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FORTIETH ANNUAL REPORT

OF THE

Mass.

STATE BOARD OF HEALTH

OF

MASSACHUSETTS.

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MEMBERS OF THE BOARD.

1908.

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Assistant to the Secretary.
WILLIAM C. HANSON,[2] M.D.

Engineer.
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Pathologist.
THEOBALD SMITH, M.D.

Analyst of Food and Drugs.
HERMANN C. LYTHGOE, S.B.

Chemist.
H. W. CLARK.

[1] Died September 11. [2] Acting secretary since August 6.

CONTENTS.

GENERAL REPORT.

In accordance with the provisions of chapter 211 of the Acts of 1905, the following report of the work of the several departments of the State Board of Health is presented for the fiscal year ended Nov. 30, 1908, on which date the Board was constituted as follows: —

HENRY P. WALCOTT, M.D., of Cambridge, *Chairman*.

JULIAN A. MEAD, M.D., of Watertown.
HIRAM F. MILLS, A.M., C.E., of Lowell.
ROBERT W. LOVETT, M.D., of Boston.
GERARD C. TOBEY, Esq., of Wareham.
JAMES W. HULL of Pittsfield.
Hon. CHARLES H. PORTER of Quincy.

On Sept. 11, 1908, Dr. Charles Harrington, secretary of the Board, died suddenly in Lynton, Eng., while absent on his vacation. The following minute to his memory was placed upon the records of the Board: —

Charles Harrington, M.D., was elected secretary of the State Board of Health on Dec. 9, 1904, and until his death performed the responsible duties pertaining to that office in an efficient and intelligent manner, and fully maintained the high standard set by his predecessors.

Thirty years ago, while a student in the medical school, Dr. Harrington decided to devote his life to preventive medicine, and from that time he steadfastly pursued the course which he had marked out so early in his career. At that time, few, even among physicians, recognized that preventive medicine was a subject worthy of the entire attention of a man seeking to be useful in the practice of medicine, and it was with surprise that his classmates learned that so bright and able a man had made such a choice. When he was elected secretary of this Board he first found an opportunity to make full use of the knowledge in hygiene that he had acquired by so many years of study, and he soon showed that the State had secured a very capable official, who had the ability and knowledge to wisely interpret and enforce the laws that protect and safeguard the health of the people.

Although his death was premature, and the next ten years should have been the most fruitful of his life, he already had shown that his choice of preventive medicine was wise, and that in no other way, probably, could he have done so much good and useful work.

CONTENTS.

CONTENTS.

CONTENTS.

CONTENTS.

Dr. Harrington's personality was pleasing and genial; his sense of humor was keen and contagious; his discrimination between right and wrong was intuitive and accurate; his scorn for all that was mean was prompt and fine. For these qualities, and for his services to the community, he was respected by all and loved by his friends.

The New Milk Standard.

On April 29, 1908, the State Board of Health was requested to furnish the Senate with the following information: —

First. — Is it desirable, from the standpoint of public health, to change the standard of milk now required by law?

Second. — Is it necessary, for the proper enforcement of the criminal law, that the standard of milk now required by law should be changed?

In reply to the questions submitted the State Board of Health submitted the following: —

The tests of milk of known purity by the State Board of Health, with other tests at their disposal, give the following general results: —

The milk of Jersey cows averages 14 per cent. of total solids and 4.92 per cent. of fat. Holsteins give an average of 12 per cent. of total solids and 3.31 per cent. of fat. Other breeds vary between these extremes, and our native cows give an average of 13 per cent. of total solids and 3.81 per cent. of fat.

Individual cows of each of these breeds vary from more than 13 per cent. above the average for the breed to 13 per cent. below in the total solids, and from 30 per cent. and more above to 40 per cent. and more below the average of fat for the breed. Hence we find Jersey cows giving milk with total solids as low as 12 per cent. and fat as low as 3 per cent. and sometimes lower, Holsteins with total solids as low as 10.5 per cent., with fat as low as 2 per cent., and natives with total solids 11.5 per cent. and fat as low as 2 per cent.

From these data it is plain that a man owning one or more Jersey cows may, under the present law, be in danger of becoming a lawbreaker if he sells any of their milk; and if he owns a herd of Holsteins, they must give richer milk than the average of their breed or he may become liable to a penalty if he sells their milk; and if he owns native cows, or cows of any of the breeds intermediate between the extremes, he may likewise incur some risk of prosecution, especially if the product of the several cows be not mixed before sale.

The milk of well-fed, healthy cows, although below the legal standard, is not known to be, and we have no reason to think it is, prejudicial to the

public health. Its food value is not so great as that of milk above the standard, but it has a food value, and if it were sold at a price proportional to its food value public health and public morals would not be thereby impaired. At present we are unable to indicate how this can be done in a practicable manner. When it becomes more common to put rich milk upon the market at a higher price, it may be well to establish a special standard by which such milk may be sold, but for the present we have to consider the general market and a suitable standard for that. This should be based upon the quality of milk supplied by those breeds of cows that keep in the most vigorous condition and are least liable to disease in this climate. From the data obtained we are unable to conclude that such cows can be depended upon to supply milk during the winter months that will strictly come up to the present standard of 13 per cent. total solids and 3.7 per cent. fat, and that it would be reasonable and favorable for the public health to have the standard for these months reduced to 12.25 per cent. total solids and 3.25 per cent. fat, and to adopt the same standards for the whole year.

The present milk standard appears to have been established by section 7 of chapter 209 of the Acts of the year 1880. It was not adopted upon the recommendation of the Board of Health then in existence, and this Board has now, for the first time, a fit occasion for the expression of an opinion upon the subject.

While we recognize the necessity of regulating the sale of milk by a standard, and the advantage of having this standard as high as is consistent with keeping the cows in healthy condition, it should be always borne in mind that of far greater importance than numerical standards in the preservation of the public health are healthy cows, kept in clean surroundings, and clean, pure milk, produced, handled, transported and delivered under sanitary conditions.

On June 13, 1908, the Legislature passed the following act relative to establishing the standard of milk: —

CHAPTER 643.

AN ACT TO ESTABLISH THE STANDARD OF MILK.

Be it enacted, etc., as follows:

Chapter fifty-six of the Revised Laws is hereby amended by striking out section fifty-six and inserting in place thereof the following: — *Section 56.* In prosecutions under the provisions of sections fifty-one to sixty-four, inclusive, milk which, upon analysis, is shown to contain less than twelve and fifteen hundredths per cent of milk solids or less than three and thirty-five hundredths per cent of fat, shall not be considered of good standard quality. [*Approved June 13, 1908.*

On June 1, 1908, the Legislature passed the following act: —

CHAPTER 570.

AN ACT TO PROVIDE FOR THE PROPER MARKING OF HEATED MILK.

Be it enacted, etc., as follows:

SECTION 1. Whoever, himself or by his servant or agent, or as the servant or agent of any person, firm or corporation, sells, exchanges or delivers or has in his custody or possession with intent to sell, exchange or deliver any milk which has been subjected to artificial heat greater than one hundred and sixty-seven degrees Fahrenheit, not having the words "heated milk" distinctly marked upon a light ground in plain black uncondensed gothic letters at least one inch in length in a conspicuous place upon every vessel, can or package from or in which such milk is, or is intended to be, sold, exchanged or delivered shall for a first offence be punished by a fine of not less than fifty nor more than two hundred dollars, for a second offence by a fine of not less than one hundred nor more than three hundred dollars, and for a subsequent offence by a fine of fifty dollars and by imprisonment for not less than sixty or more than ninety days. If such vessel, can or package is of the capacity of not more than two quarts, said words may be placed upon a detachable label or tag attached thereto and said letters may be less than one inch in length, but not smaller than brevier gothic capital letters.

SECTION 2. Nothing in this act shall be construed as applying to condensed milk or to milk which has been concentrated to one half its volume or less. [*Approved June 1, 1908.*

TUBERCULOSIS EXHIBITION.

The Legislature of 1908 on June 12 passed a resolve providing for an exhibit at the International Congress on Tuberculosis.

CHAPTER 140.

RESOLVE TO PROVIDE FOR AN EXHIBIT AT THE INTERNATIONAL CONGRESS ON TUBERCULOSIS.

Resolved, That there be allowed and paid out of the treasury of the commonwealth a sum not exceeding thirty-eight hundred dollars, to be expended under the direction of the state board of health for the expense of collection, transportation, installation, care and return of a suitable state exhibit at the international congress on tuberculosis to be held in the city of Washington in the District of Columbia from September twenty-first to October twelfth, inclusive, in the year nineteen hundred and eight. [*Approved June 12, 1908.*

In accordance with the provisions of this resolve, with the approval of the State Board of Health, the Massachusetts State Committee for the International Congress on Tuberculosis collected an exhibition which

was sent to Washington and arranged with the exhibits from other States at the new National Museum. The Massachusetts exhibit represented practically every phase of the tuberculosis campaign throughout the Commonwealth. The State of Massachusetts was awarded a silver medal, and the Massachusetts State Committee of the International Congress a gold medal for the bound volume on "Tuberculosis in Massachusetts." This volume contains a valuable contribution to the literature on tuberculosis, bringing together related facts and history heretofore inaccessible. The four principal parts of the State exhibit were prepared by (1) the State Board of Health, (2) the State Sanatorium at Rutland, (3) the Boston Consumptives' Hospital, and (4) the Boston Association for the Relief and Control of Tuberculosis.

The series of photographs sent by the State Board of Health was unique. It was the choicest collection of photographs bearing upon the subject of occupational hygiene that has been shown in this country. While the collection contained certain industries which are commonly regarded as being conducive to tuberculosis of the lungs, it included many large views of the main processes of manufacture in these and in other industries conducted in establishments where the conditions as to light, ventilation, dust, gases, humidity, etc., were practically ideal. The photographs were constantly surrounded by workingmen of all kinds, and received a great deal of attention. They were awarded a silver medal.

The State Sanatorium at Rutland, the first State sanatorium in this country, prepared a large model of the entire institution, with smaller models of the various wards and shacks. In addition, there were plans and photographs. The model, constructed by an ex-Rutland patient, said to be the most attractive and effective one of its kind in Washington, was assigned a silver medal.

The Boston Consumptives' Hospital displayed maps, charts, plans, photographs and several large models. Legends were posted, describing the work carried on in Boston, the work and buildings in Mattapan, the day camp and the out-patient nursing department. Both the hospital and the dispensary were awarded silver medals.

The most attractive feature of the section prepared by the Boston Association for the Relief and Control of Tuberculosis was a series of models, diagrams and charts which showed how the subject of home hygiene was taught at the Louisa M. Alcott and Hawthorne children's clubs in Boston. In these clubs, by means of dolls, small beds, models of houses, etc., children are taught in a practical way the simple rules of health as to bathing, dressing, ventilating their rooms and other matters of hygiene. Various compositions written and illustrated by the

children were shown. This work attracted a great deal of attention, both among the laity and physicians. The Society for the Relief and Control of Tuberculosis was awarded a gold medal. Honorable mention was made for the work done by the classes instructing delicate children on personal hygiene, and for their out-of-door school for children ill with tuberculosis. A silver medal was awarded the Louisa M. Alcott and the Hawthorne clubs for the illustration of their work and methods in the training of children in laws of hygiene.

The Associated Committees of the Massachusetts Medical Society, organized for the study and prevention of tuberculosis in Massachusetts, showed by an elaborate series of maps what has been accomplished throughout the State in the way of establishing tuberculosis classes, day camps, dispensaries and anti-tuberculosis associations.

The Massachusetts Commission on Hospitals for Consumptives showed plans of the proposed hospitals for patients ill with tuberculosis.

The Boston District Nursing Association showed the methods of district nurses' co-operation, including the assistance of the nurses at the dispensary for examination of patients and their assistance at the patients' tenement homes.

The plans of the tuberculosis wards of the State Hospital at Tewksbury met with approval as being excellent types of moderate-priced construction for hospitals for advanced cases of tuberculosis, and were awarded a gold medal.

The pathological collection of the Boston University Medical School, which consisted of beautifully mounted specimens, showing practically every form in which tuberculosis is met with in human beings and in animals, was regarded as the best exhibit of its kind, and was awarded a silver medal.

The models presented by the Millet and Sharon sanatoria were commendable, as showing the methods of construction adopted and the manner of caring for patients at these private institutions.

The plans and photographs of the Channing Home, the oldest institution for tuberculosis in Massachusetts, gave a very clear idea of the exterior and interior of the building, where excellent work is done in the care of tuberculosis patients.

The House of the Good Samaritan, one of the most elaborate and best-equipped institutions of its kind in the country, displayed some beautiful photographs of the institution, including plans and models of the day camp.

A gold medal was awarded the Emmanuel Church Tuberculosis Class for their display of models, charts and photographs, which showed that much good could be done by tuberculosis classes.

Other contributors were as follows: the Brookline Day Camp; the Cambridge Anti-Tuberculosis Association; the Cambridge Board of Health; Cullis Consumptives' Home, Dorchester; Danvers Insane Asylum; Fitchburg Society for the Control and Cure of Tuberculosis; Free Home for Consumptives, Dorchester; Haverhill .Anti-Tuberculosis Association; Holyoke Association for the Prevention and Relief of Tuberculosis; Lawrence Anti-Tuberculosis League; Long Island Hospital and Almshouse, Long Island, Boston; Massachusetts State Federation of Women's Clubs; Portuguese League for Assistance of Consumptives, New Bedford; Springfield Association for the Prevention of Tuberculosis; Tuberculosis Committee of the Associated Charities, Malden; Tuberculosis Committee of the Associated Charities, Salem; Worcester City Hospital Dispensary.

Acts relative to the Protection of Water Supplies.

On May 7, 1908, the Legislature passed the following act: —

Chapter 499.

An Act to provide for the Protection of Sources of Water Supply.

Be it enacted, etc., as follows:

Section 1. Cities, towns and fire districts duly established by legislative authority may, with the consent and approval of the state board of health, given after due notice and a hearing, take, or acquire by purchase or otherwise, and hold any lands, buildings, rights of way and easements within the watershed of any pond, stream, reservoir, well or other water used by them as a source of water supply, which said board may deem necessary to protect and preserve the purity of the water supply.

Section 2. If any lands, buildings, rights of way or easements are taken under authority hereof, the city, town or fire district shall, within ninety days thereafter, file and cause to be recorded in the registry of deeds for the county or district in which the same are situated, a description thereof sufficiently accurate for identification, with a statement of the purpose for which the same are taken, signed by the water commissioners of said city, town or district. Upon the filing of said description and statement the title in fee simple to the lands, buildings, rights or easements so taken, shall vest in the city, town or district. All lands taken, purchased or otherwise acquired under the provisions of this act shall be under the control of the board of water commissioners of the city, town or district acquiring the same, who shall manage and improve them in such manner as they shall deem for the best interest of the city, town or district.

Section 3. Cities, towns and districts shall pay all damages sustained by any person or corporation by the taking of any lands, buildings, rights or easements under the authority of this act; and if the parties cannot agree upon the amount of the same, they may be recovered in the manner pro-

vided by law in the case of land taken for the laying out of highways: *provided,* that application therefor is made within three years after the said taking.

SECTION 4. All damages to be paid by a city, town or district by reason of any act done under the authority of this act may be paid out of the proceeds of the sale of any bonds authorized by law to be issued by such city, town or district for water supply purposes or from any surplus income of the water works available for the purpose.

SECTION 5. After the actual taking by a city, town or fire district of property in another city or town for the purposes of this act, the same may be valued by the assessors of the city or town in which such property is situated on the basis of the average of the assessed value of the land and buildings for the three years preceding the acquisition thereof, the valuation for each year being reduced by all abatements thereon; but any part of such land or buildings from which any revenue in the nature of rent is received shall be subject to taxation, and the city, town or fire district acquiring such property shall pay to the city or town in which it is situated taxes or sums in lieu of taxes at the rate per thousand of all taxes in such city or town for that year on the valuation so determined. Cases of dispute as to valuations arising under this act shall be governed by the provisions of sections eleven and twelve of chapter twelve of the Revised Laws, and of all amendments thereof now or hereafter made.

SECTION 6. All acts and parts of acts relating to the acquirement of lands by cities or towns for the protection of water supplies inconsistent herewith are hereby repealed.

SECTION 7. This act shall take effect upon its passage. [*Approved May 7, 1908.*

On May 26, 1908, the Legislature passed the following act: —

CHAPTER 539.

AN ACT TO PROVIDE FOR THE BETTER PROTECTION OF THE DOMESTIC WATER SUPPLIES OF THE COMMONWEALTH.

Be it enacted, etc., as follows:

SECTION 1. Any police officer or constable of a city or town in which any pond, stream or reservoir used for the purpose of domestic water supply is wholly or partly situated, acting within the limits of his city or town, and any executive officer of a water board, board of water commissioners, public institution or water company, furnishing water for domestic purposes, or agent of such water board, board of water commissioners, public institution or water company, duly authorized in writing therefor by such boards, institution or company, acting upon the premises of such board, institution or company and not more than five rods from the water, for such supply may, without a warrant, arrest any person found in the act of bathing in a pond, stream or reservoir, the water of which is used for the purpose aforesaid,

and detain him in some convenient place until a complaint can be made against him therefor.

SECTION 2. This act shall take effect upon its passage. [*Approved May 26, 1908.*

On June 4, 1908, the Legislature passed the following act: —

CHAPTER 585.

AN ACT RELATIVE TO THE IMPROVEMENT OF GREEN HARBOR IN THE TOWN OF MARSHFIELD.

Be it enacted, etc., as follows:

The board of harbor and land commissioners and the state board of health, acting jointly, are hereby authorized and directed to cause an examination to be made of Green Harbor in the town of Marshfield, and of the dam and dike constructed across Green Harbor river under the provisions of chapter three hundred and three of the acts of the year eighteen hundred and seventy-one, and of the marshes above and below said dike, in order to determine what improvement can be made in said harbor by the removal, in whole or in part, of said dike, or by the placing of sufficient tide gates therein, or otherwise; and after such examination, and after such other inquiry as said joint board may see fit to make, it shall report in full to the next general court, with any recommendations which it may deem proper, looking to the restoration of Green Harbor, substantially to the condition in which it was before the construction of said dike. The said joint board is authorized to report in print with plans. [*Approved June 4, 1908.*

The report called for follows: —

In accordance with the provisions of chapter 585 of the Acts of 1908, which is as follows: —

AN ACT RELATIVE TO THE IMPROVEMENT OF GREEN HARBOR IN THE TOWN OF MARSHFIELD.

The board of harbor and land commissioners and the state board of health, acting jointly, are hereby authorized and directed to cause an examination to be made of Green Harbor in the town of Marshfield, and of the dam and dike constructed across Green Harbor river under the provisions of chapter three hundred and three of the acts of the year eighteen hundred and seventy-one, and of the marshes above and below said dike, in order to determine what improvement can be made in said harbor by the removal, in whole or in part, of said dike, or by the placing of sufficient tide gates therein, or otherwise; and after such examination, and after such other inquiry as said joint board may see fit to make, it shall report in full to the next general court, with any recommendations which it may deem proper, looking to the restoration of Green Harbor, substantially to the condition in which it was before the construction of said dike. The said joint board is authorized to report in print with plans.

the Board of Harbor and Land Commissioners and the State Board of Health met on July 2, 1908, for the purpose of organization as a Joint Board.

Henry P. Walcott was elected chairman; Frank W. Hodgdon was appointed secretary; and Frank W. Hodgdon, C.E., and X. H. Goodnough, C.E., were appointed as engineers to make the necessary investigations. They were directed to proceed at once and cause a survey to be made of Green Harbor below the dike, for comparison with surveys made in previous years; also to make an examination of the marshes above the dike, to see what changes, if any, had occurred since the surveys made in 1896 and 1897, and to report the results of their examination and their recommendations.

The Joint Board has personally inspected the locality concerned, and has held public hearings at Green Harbor and also at the State House.

The material facts in the history of this region may be found in the report of the Joint Board, consisting of the Harbor and Land Commissioners and the State Board of Health, made to the Legislature in January, 1898.

This Joint Board, after carefully considering the information collected as above described, including the report of its engineers, which may be found in the Appendix of this report, believes, as did the previous Joint Board, that the experiment of reclaiming the marshes above the present dike has been costly to the Commonwealth, of slight benefit to the marsh owners who built the dike, and a source of undoubted injury to this small harbor. The relief, however, from this injury cannot, in our opinion, be obtained by removing the dike, because the level of the meadows as they now exist above the dike is so low that, if the dike were removed, a tidal scour would be established in Green Harbor capable of destroying much valuable property and creating a serious nuisance to the whole neighborhood.

For this reason the Board is of the opinion that it is inexpedient to remove the dike, but believes that by either of the two plans proposed by its engineers a substantial improvement in the harbor can be made, sufficient to be considered as restoring it substantially to the condition in which it was before the construction of the dike.

While stating these views as to what it is possible to do, this Board desires to distinctly state that it makes no recommendations as to the expediency of making the necessary expenditures to carry out any further improvements.

On June 11, 1908, the Legislature passed the following act: —

CHAPTER 607.

AN ACT TO PROVIDE FOR AN INVESTIGATION AND REPORT BY THE STATE BOARD OF HEALTH AS TO THE FLOODING OF LANDS BORDERING LAKE QUANNAPOWITT AND ITS TRIBUTARIES AND AS TO THE PROPER HIGH WATER ELEVATION OF SAID LAKE.

Be it enacted, etc., as follows:

SECTION 1. The state board of health is hereby authorized and directed to examine Lake Quannapowitt in the town of Wakefield, and the watershed

thereof, to ascertain if lands bordering on the lake or its tributaries in the towns of Wakefield and Reading are flooded, or if the condition of such lands is rendered objectionable or injurious to health by reason of any excessive, unnecessary or illegal raising of the waters of the lake, or by any pollution thereof from any source. The board is also authorized and directed to determine the proper, lawful high water mark of Lake Quannapowitt, and to report the results of its investigations, with such recommendations as it may deem expedient, to the next general court on or before January fifteenth.

SECTION 2. This act shall take effect upon its passage. [*Approved June 11, 1908.*

The report called for follows: —

The act of the General Court of 1908, which requires the State Board of Health to investigate the flooding of lands bordering Lake Quannapowitt and the high-water elevation of the lake, is as follows: —

SECTION 1. The state board of health is hereby authorized and directed to examine Lake Quannapowitt in the town of Wakefield, and the watershed thereof, to ascertain if lands bordering on the lake or its tributaries in the towns of Wakefield and Reading are flooded, or if the condition of such lands is rendered objectionable or injurious to health by reason of any excessive, unnecessary or illegal raising of the waters of the lake, or by any pollution thereof from any source. The board is also authorized and directed to determine the proper, lawful high water mark of Lake Quannapowitt, and to report the results of its investigations, with such recommendations as it may deem expedient, to the next general court on or before January fifteenth.

SECTION 2. This act shall take effect upon its passage.

Lake Quannapowitt is located in the northerly part of the town of Wakefield, and is wholly within the limits of that town, but its northwesterly shore is within one-quarter of a mile of the boundary of the town of Reading. The area of the lake is 230 acres, or .36 of a square mile. Its watershed, including the area of the lake, is 4.33 square miles. It includes a part of the town of Wakefield, nearly all of which is very densely populated, and a large part of the town of Reading, including the densely populated district of that town. The estimated population within the watershed at the present time is 8,100, or 1,870 persons per square mile. The population is increasing and the growth is likely to continue, on account of the nearness of the towns to the city of Boston and the fact that they are within the limits of suburban transportation service.

The low lands referred to in the act are located on the westerly side of the lake, between the towns of Wakefield and Reading, but lie nearer the thickly settled portion of Reading than Wakefield. A survey of the lands has been made, to determine their area and elevation and their general physical condition, the results of which show that there is a total area of

about 660 acres of meadow lands lying in this region, of which 384 acres, or 58 per cent., are within the limits of the town of Reading, and 276 acres, or 42 per cent., within the limits of the town of Wakefield. Of the total area of 660 acres, 185 acres, or 28 per cent., are below grade 88 (Boston city base); 235 acres are between grade 88 and grade 90; and the remainder, 240 acres, are between grades 90 and 92. These facts are summarized in the following table: —

Elevation of Meadow.	East of Railroad Street.		West of Railroad Street.		Total (Acres).
	In Reading (Acres).	In Wakefield (Acres).	In Reading (Acres).	In Wakefield (Acres).	
Below 88,	41.5	113.3	5.9	24.6	185.3
Between 88-90,	77.4	17.9	48.0	91.4	234.7
Between 90-92,	169.3	14.1	41.7	14.9	240.0
Total,	288.2	145.3	95.6	130.9	660.0

Of the total area of 660 acres, about 500 acres are swamps, covered with bushes and trees in various stages of growth and degrees of density, and a large part of these areas was found to be wet even in the very dry season of 1908. Of the cleared lands, areas aggregating 75 acres were found in the past very dry season to be in a wet and spongy condition and practically valueless; while 85 acres were in a fairly satisfactory condition, and from a portion of this area it is said that a hay crop is usually obtained.

Information has been sought as to the valuation of the meadow lands near Lake Quannapowitt, from the assessors of the towns of Reading and Wakefield. It has not been practicable to obtain very definite information as to the valuation of a part of this area, especially the portions in Wakefield, where a large part of the meadow land is very poor. The valuation of 412 acres, which does not include some of the worst portions, averages about $53 per acre, and the valuation of 126 acres of that area averages $21 per acre, varying from $17 to $31. The valuation of about 65 acres of the higher meadow lands ranges from $110 to $115 per acre.

General Conditions affecting the Height of Water in Lake Quannapowitt.

The height of water in Lake Quannapowitt depends upon several circumstances, but chiefly during about half the year — from October 20 to April 20 — upon the height of the dam on the Saugus River at Vernon Street, about 3,300 feet or a little less than two-thirds of a mile below the outlet of the lake. At the outlet of the lake the river passes under Lowell Street, which is bordered on its westerly side by an electric car line running from Reading to Wakefield. The bottom of this culvert is lowest at its upper end, where its elevation is at about grade 85. The elevation increases towards the outer end, and the bottom of the stream a short distance below the culvert reaches a level of about 85.45. The culvert is built of rough stones,

and has a very uneven, gravelly and rocky bottom. It has an average cross-sectional area of about 13 square feet, but the dimensions of the culvert beneath the electric car tracks differ from those beneath Lowell Street. The elevation of the top of the overflow of the dam at Vernon Street, as found by recent observations, is grade 88.

Below the culvert the bottom of the stream falls off rapidly from about 85.4 until it reaches a level of about 83.5 at a point about 400 feet below the culvert. It then falls gradually for a distance of about 1,800 feet, reaching grade 82.7 at a point about 960 feet above the dam; it then rises to about grade 83.7 at a point 350 feet from the dam, and falls at the dam to grade 82; below the dam and highway at Vernon Street the bottom of the stream is at grade 78, and it then falls off rapidly to meadows lower down. The course of the stream from Lake Quannapowitt to the dam is through extensive meadows, the elevation of the surface of which near the stream is at about grade 85.5.

Water Rights at Dam at Vernon Street.

A careful examination has been made of town records, deeds and other information, to determine the legal rights of flowage at the dam at Vernon Street and the legal elevation of the water in Lake Quannapowitt. The records are incomplete, but so far as they are available they show clearly a right to raise the water at the Vernon Street dam from October 20 to April 20. So far as can be learned, no specific height for this dam has ever been established; but it is evident, from an examination of the dam and its surroundings, that there has been no material change in its height for many years.

Maximum Height of Water in the Lake and Effect upon the Meadows.

It will be noted at once by referring to the table on page 3 that raising the water at the dam at Vernon Street to grade 88, which the owners of that dam appear to have the right to do between October 20 and April 20, must cause the flooding of at least 185 acres of the low lands near Lake Quannapowitt; and that an additional area of 235 acres would then be less than 2 feet above the surface of the water, even if there were no slope in the water between them and the dam.

On account of the extensive meadows between the lake and the dam, which are flooded when the water is at grade 88, it is not probable, considering the size of the culvert at the outlet of the lake, that there is ordinarily any very considerable loss of head between them; but at times of high flow the loss of head between the lake and the dam may amount to several inches. The greatest height to which the water in the lake has risen, so far as we have been able to determine from satisfactory evidence, is grade 89.3 or 89.4, which occurred in the spring, about four years ago. The high water at that time was very probably due to the great rain which occurred on April 27, 28 and 29, 1904. The flow of the adjacent Mystic

River for that period, as calculated by the engineers of the Metropolitan Water Board,[1] was as follows: —

Date.	Cubic Feet per Second.	Date.	Cubic Feet per Second.
April 26,	2.36	April 30,	14.10
April 27,	5.75	May 1,	9.90
April 28,	15.35	May 2,	7.13
April 29,	18.40	May 3,	6.78

It is said that the high run-off in that storm was probably due in part to the previous saturation of the ground, and it is highly probable that at the time of that freshet the water above the dam at Vernon Street had not been drawn off.

It is obvious that the maximum height to which the water in the lake may rise in extreme freshets is probably not greatly above the figure already given, because of the great storage in the lake and the meadows about it and within its watershed. A rise of 1 foot in the lake alone, without taking the storage on the meadows into account, would require a flow of more than 30 cubic feet per second per square mile for a day, if no water were flowing out of the lake. On the other hand, it appears from such evidence as has been collected from the family of one of the former owners of the dam at Vernon Street and from others, that it is necessary to watch the culvert at Lowell Street closely at times of high flow, else it quickly becomes obstructed with floating sticks, leaves and other débris, which the prevailing winds in this region tend to drive from all parts of the lake toward the outlet. It is probable enough that the highest freshet of recent years did not carry the water above grade 89.4; but it is also likely that, owing to obstructions at the culvert at times of high flow, the level of the water in the lake frequently rises above grade 88.

Height of Water in the Lake in the Drier Portion of the Year.

The water rights at the dam at Vernon Street apparently do not include the right to raise the level of the water in the Saugus River during the period from April 20 to October 20; and during that period of the year, if the water in the river is allowed to flow freely in the bed of the stream past the dam, the conditions affecting the height of water in Lake Quannapowitt and the low lands about it and its tributaries are very different from those which exist when the dam is in use.

The height of low water in the lake appears to have been determined by the town as early as 1844. On July 17, 1871, a committee was chosen by the town of Wakefield to determine the low-water mark in the lake; and this committee and a committee of the mill owners on the stream below,

[1] From page 52 of Report on Improvement of the Upper Mystic River and Alewife Brook by means of Tide Gates and Large Drainage Channels, by John R. Freeman, Civil Engineer, September, 1904.

having failed to find trace of the log supposed to have been set to fix the low-water mark in the earlier year mentioned, proceeded to fix low-water mark anew as follows: —

First. — That the stream shall continue to flow, during the present season, without further obstruction, until the water is on the increase.

Second. — That the basis for the level of the water mark shall be a foundation timber on the north side of the stream, 49 feet from the west edge of the road bridge.

Third. — That the low-water mark shall be at 12 inches above the level of said timber, from the first day of April to the first day of August; and from the first day of August to the first day of April the mill owners shall have the right to draw the water 6 inches lower than the said low-water mark.

The committee further reports: —

The committee procured a stone 12 feet long and 2 feet thick, cut down in the center so that a plank can be put in and taken out to the depth of 6 inches; but the stone did not arrive soon enough to place while the bed was dry.

That the low-water mark might be found in case the timber should be washed away, its elevation was determined by a survey with reference to certain neighboring objects. The stone appears to have been washed out and misplaced, and was subsequently reset in 1876 and its elevation again determined with reference to what was apparently the old log by which the elevation was determined five years before. There is no record of a change in the stone since 1876. Its elevation to-day is grade 86.8. In the middle the stone is cut down to make an opening 4 feet long and 6 inches below the level of the remainder of the stone, and the bottom of the low part, which is now the low-water mark of the pond, is grade 86.3. During the past very dry season the water in the lake fell below that level. The agreement of 1871 fixes the low water at the top of the stone from the first of April to the first of August, and at the bottom of the notch in the stone from the first of August to the first of April, apparently regardless of the flowage rights of the proprietors of the Vernon Street dam below. It does not appear that the right to use a stop-plank to keep the water up from April to August has been exercised, at least for many years.

As already stated, the fall in the Saugus River below the culvert at Lowell Street is considerable, and the elevation of the surface of the meadows through which it flows is at about grade 85.5, or considerably below the level of the bottom of the notch in the stone at the outlet of the lake; so that the height of the water in the lake from the time the water is drawn off at the Vernon Street dam in the spring until the dam is used again in the fall is probably not influenced, unless on very rare occasions, by the height of water below the culvert at Lowell Street. Under the existing circumstances, the height of water in the lake from April to October is dependent upon the flow from the watershed and the height to

which the water must rise to carry the flow over the stone and through the culvert below, and the amount of obstruction in the culvert or at its upper end.

In the highest freshet that has occurred on the Mystic River for many years in the period between April 20 and October 20, the water in the lake, if the water at the dam at Vernon Street had previously been drawn off, would probably rise to about grade 87.2; but ordinarily the flow between those dates would not be much more than sufficient to fill the notch in the stone; and, on account of the great storage in the lake which tends to equalize the flow, the level of the lake in the period between April 20 and October 20 would probably rarely rise above grade 87 under existing conditions, if the culvert were kept free of obstruction.

The lowest of the meadows are apparently at about grade 87.2. There are a number of places, small in area, where the elevation was even less, and 185 acres are below grade 88; so that in the summer season, when the water is at the level of the bottom of the overflow and none is flowing out of the lake, the level of the lake is only about .9 of a foot below the level of the lowest meadows, and with ordinary flows of water only from 5 to 6 inches below them.

Condition of the Streams and Drains in the Meadows.

In the driest part of the present year the level of the water in Lake Quannapowitt was, as already stated, below the level of low water, and was observed late in the year at grade 86. This level is below any of the meadows, yet the examinations have shown that under these conditions large areas of these low lands were in a wet and spongy condition.

An examination of the channels of the streams flowing through them and the culverts and channels beneath the highways shows very clearly the cause for these conditions.

The main brooks entering the lake are in two groups, one of which consists of the Charles Street Brook, the Salem Street Brook and the Haven Street Brook, all of which apparently unite in one stream and flow into the lake near its extreme northwesterly end. The Charles Street Brook has a well-defined channel in its upper waters, but after entering the meadows its channel disappears, and the water brought down by the brook finds its way over the meadow to the channel of the Salem Street Brook lower down. The Salem Street Brook has also a well-defined channel in all its upper waters, but farther down this channel also becomes obscure, while in other places there are two distinct channels. The same is true of the Haven Street Brook, while the main brook into which these streams discharge has also an ill-defined channel and in places two channels.

The other main tributary enters the lake farther to the west, and is formed by the junction of Appleton Brook and the stream known as the "head of Saugus River." Appleton Brook has a well-defined channel in its upper waters, but below Cross Street at two points the channel disap-

pears entirely. The head of Saugus River has a very crooked but somewhat better channel through the meadows, especially between Railroad Street and the lake.

It is evident, from the condition in which these meadows were found during the past dry summer, when the surface of the lake was for a considerable time below its low-water level, that the condition of the meadows will continue to be objectionable until they are properly drained. In their present condition they are a menace to the health of the neighboring towns.

Pollution of the Lake and its Tributaries.

Numerous chemical analyses have been made of the waters of the lake and its tributaries at various times, including a large number during the past year, the results of which show that all of the tributaries of the lake are very badly polluted. Both Reading and Wakefield have long been provided with public water supplies, and a system of sewerage was introduced in Wakefield a number of years ago, which receives much of the sewage from the thickly populated territory in that town within the watershed of the lake. Surface drains have also been built in that town, a few of which discharge into the lake. There are no sewers as yet in the town of Reading, but a considerable surface-drainage system has been constructed, discharging into the brooks and their tributaries. Examinations of the various brooks show that they are polluted in many places by sink drainage, and there are numerous vaults and cesspools close to these streams and their tributaries from which it is evident that much seepage finds its way into them. The chemical analyses show that the water flowing in the streams in the past summer was made up largely of partly purified sewage.

The most considerable pollution discovered at any one point is caused by a laundry in Reading, from which about 5,000 gallons per day of dirty water flow over the ground and into one of the brooks. There appears to be a sufficient area of land available upon which this water might be filtered and the pollution of the brook by it prevented. Many of the drains in Reading are covered, so that it is impracticable to determine definitely the sources or character of their pollution.

The watersheds of two of the most seriously polluted tributaries of the lake are wholly within the limits of Wakefield, but these streams are very small. The watersheds of the other streams lie partly in Wakefield and partly in Reading, but the pollution of most of the streams entering the northerly end of the lake is caused wholly by the population of Reading.

The quantity of pollution entering the lake has a very unfavorable effect upon the quality of its water; but, while the amount of pollution is so great as to make it a very objectionable source from which to take water for drinking, its waters have not been polluted to such an extent as yet as to affect its appearance in the lake, or give the water an objectionable odor noticeable to those living in its neighborhood or going upon it in boats.

Summary.

Summarizing the results of the foregoing observations, the Board finds that the extensive areas of low lands adjacent to Lake Quannapowitt in Wakefield and Reading have no adequate system of drainage, and large portions of them even in the dry summer and autumn of 1908 were wet and contained numerous pools of stagnant water. Their condition is a menace to the health of a large and growing population living about them within the watershed of the lake, and for the protection of the public health they should be properly drained as soon as practicable.

In order to drain these low lands adequately, it will be necessary to remove the dam at Vernon Street, enlarge and deepen the culvert under Lowell Street, providing also a suitable weir at that point, and construct drainage channels through the meadows of sufficient capacity and at a sufficiently low level to carry off readily all of the water brought down to the meadows by the various streams which enter them and discharge it into the lake.

The value of the flowage rights at Vernon Street is not great, and that property, including the mill and appurtenances, could apparently have been purchased at any time within recent years for a small sum compared with the advantage to be obtained from its ownership in draining the meadows about the lake. It would be a simple matter to deepen and enlarge the culvert under Lowell Street, and provide a weir at the outlet of the lake of such length, probably not over 100 feet, as to allow the water to flow off with little fluctuation in the height of the lake.

It is not practicable to tell, without more extended surveys and the completion of designs for drainage, whether the low lands in question can be drained satisfactorily without holding the water of the lake lower than its present low-water level.

The Board is unable to find that any legal high-water mark for Lake Quannapowitt has ever been established.

The Legislature of 1908 passed the following resolve, directing the Board to investigate and report upon the sanitary condition of the bed, banks and waters of the Merrimack River, and of the streams tributary or adjacent thereto, in any city or town bordering upon the said river or streams: —

Chapter 114.

Resolve to provide for an Investigation of the Sanitary Condition of the Merrimac River.

Resolved, That the state board of health is hereby authorized and directed to investigate and report upon the sanitary condition of the bed, banks and waters of the Merrimac River, and of the streams tributary or adjacent thereto, in any city or town bordering upon the said river or streams. The

board shall ascertain whether the condition of said river or streams or the banks thereof is injurious or dangerous to public health, by reason of the entrance of sewage or of refuse from factories, or from other causes; and if they find that any circumstances injurious or dangerous to the public health exist, they shall recommend a plan or plans for their removal, and shall report the same to the next general court. [*Approved May 28, 1908.*

The report called for follows: —

In accordance with chapter 114 of the Resolves of 1908, the State Board of Health makes the following report upon the sanitary condition of the bed, banks and waters of the Merrimack River and of the streams tributary thereto. No appropriation was made for the proposed investigation, and it has been made with the help of the general funds of the Board and those for the examination of sewer outlets, with the results contained in the appended report of the chief engineer of the Board. The facts therein are made a part of this report.

The river as it enters the State from New Hampshire has on its main line and branches received sewage from 180,000 people, together with large manufacturing wastes. The resulting pollution, as indicated by the amount of albuminoid ammonia, has in the past twenty years increased about 40 per cent.; but, as in the early years of this period the flow of water in the river was greater than usual and in the past few years has been less, ending with the driest year of the period, the actual increase in pollution is not as much as 40 per cent. The pollution of the river above Lawrence has in the same time increased at about the same rate. Above Haverhill observations are limited to the past ten years, in which the increase in percentage per year has been about the same as that above Lawrence.

For the past few years the pollution above Lawrence has been 35 per cent. more than that above Lowell, and the pollution above Haverhill has been 31 per cent. more than that above Lawrence, while the increase in passing Haverhill is about 7 per cent.

Farther down the river the water is less polluted, so that, entering the State with a certain amount of pollution, this pollution is, where greatest, increased about 90 per cent. by passing the cities of Lowell, Lawrence and Haverhill.

At present this stream of water is not in a condition to be injurious to the public health, and by proper regulation it may be kept many years, perhaps generations, free from danger.

There are, however, many localities in each of these cities, near the outlet of sewers, where the stream is locally polluted, the sewage not being disseminated through the stream; and where the bed and banks at night and on Sundays, when the mills are not running, and at low tide near the lower city, are exposed, coated with the refuse of sewage and of some manufacturing wastes. At these places the conditions are injurious to the health of those living or working near.

These conditions may be obviated in general by extending the sewer by an iron pipe, smaller than the sewer, but large enough to convey the ordinary sewage, to beyond the edge of the stream at the lowest stage and discharging under water, so that a clean stream of water may continually flow between the shore and the outlet. In this way the sewage becomes diluted by the water into which it is discharged, and the shore is kept clean.

Of the manufacturing wastes, the most obvious and the one that causes the most complaint upon this river is that resulting from the scouring of wool. This process of washing and discharging the effluent containing large quantities of grease into the river results in a grease-covered shore and bed for a long distance down stream. The grease associates with and holds other objectionable matter, and, while we cannot say that it has up to this time been injurious or dangerous to the public health, it has become very disagreeable. The boatmen at Haverhill complain of the black grease adhering to their boats. It is at present a very disagreeable addition to the river, and may become injurious to the public health.

In other countries, and to some extent in this, the grease, which is the objectionable element in the effluent, is removed and made into valuable articles of commerce.

It would probably be no great hardship if the scourers of wool were required to keep the grease out of the river. If this were done, the appearance of the river would be very much improved and the ground for much of the complaint in regard to its present condition removed.

The pollution entering this river from beyond the State renders it impracticable to include it with those rivers used for water supplies; but the local nuisances and the increasing pollution require that more complete regulation be applied to this river, and to this end the Board recommends that section 123 of chapter 75 of the Revised Laws be modified to read as follows: —

SECTION 123. The provisions of the five preceding sections and of so much of sections one hundred and twelve to one hundred and seventeen inclusive as refer to domestic water supplies shall not apply to the Merrimack or Connecticut rivers, nor to so much of the Concord river as lies within the limits of the city of Lowell, nor to springs, streams, ponds or water courses over which the metropolitan water board has control.

WATER SUPPLY AND SEWERAGE.

The State Board of Health presents herewith a report of its doings for the twelve months ended Nov. 30, 1908, under the provisions of laws relating to the protection of the purity of inland waters, as required by chapter 75, section 115, of the Revised Laws.

The Board has received during the year 134 applications for advice with reference to water supply, sewerage, sewage disposal and matters relating thereto. Of these, 92 related to water supply, 6 to ice supply, 30 to sewerage, drainage and sewage disposal, and 6 to miscellaneous matters.

Examination of Water Supplies.

Public water supplies were introduced during the year in the towns of Wrentham, Wareham, Westford and Marion, and at the end of the year 188 out of the 354 cities and towns in the State were provided with public water supplies. All of the cities and towns having a population, according to the census of 1905, in excess of 3,500 are now provided with public water supplies, except the towns of Barnstable, Blackstone, Dartmouth, Dudley, Templeton and Tewksbury. The cities and towns having public water supplies contain approximately 93 per cent. of the total population of the State.

While only 4 towns introduced water supplies for the first time, the year was nevertheless an active one in water works construction, and important enlargements and improvements were made in many existing works. Among the most important of these may be mentioned the introduction of water from a new source of supply for the town of Provincetown, where the water from the works formerly in use has been extremely objectionable on account of the presence of an excessive quantity of iron. It was found impracticable to obtain water free from an excess of iron within the limits of the town, and the results of many experiments had shown that it was very difficult to purify the water without the use of chemicals. The new supply is taken from the gravelly areas in North Truro, where an abundance of excellent water is obtained from the ground. The result of the introduction of a supply of water of good quality has been a great increase in its use.

At Newburyport works have been completed for taking water from the Artichoke River and filtering it through the natural soil of the gravelly areas in the valley of Jackman Spring. The works of this city are now capable of furnishing an ample supply of good water for its requirements.

The Southbridge Water Company is constructing similar works for the purification of the water of one of its storage reservoirs.

Work has also been in progress during the year upon the construction of new water supplies in several towns, and important changes are being made in the water supplies of Springfield, Pittsfield, Waltham and other places.

The city of Woburn, for the purpose of enlarging and improving its water supply and installing new meters, was authorized by the provisions of chapter 578 of the Acts of the year 1908 to take, by purchase or otherwise, and hold the waters of any pond or stream or of any ground sources of supply, by means of driven, artesian or other wells, within the limits of the city, and to take lands, rights of way and easements

necessary for collecting, storing, holding, purifying and preserving the purity of the water, with the proviso that no source of water supply and no lands necessary for preserving the quality of such water should be taken or acquired without obtaining the advice and approval of the State Board of Health, and that the location of all dams, reservoirs and wells to be used as sources of supply under the act should be subject to the approval of the Board.

On June 16 the city of Woburn, through its engineer, submitted plans for certain improvements in the water supply of the city, including the construction of a well near the pumping station, and on July 2 the Board, acting upon the matter, advised that the construction of the well be omitted, and did not approve the plan. Notwithstanding the action of the Board the city proceeded to construct the well, which the Board is informed is completed and now in use.

The usual chemical and microscopical analyses of the waters of public water supplies have been continued, and many bacterial examinations of ground waters have been made. The total number of sources of water supply examined during the year was 280, most of which were inspected by the engineer of the Board or his assistants.

The year 1908 was a remarkably dry one, the total rainfall on the watershed of the Sudbury River being 36.15 inches, or 9.55 inches less than the average for thirty-four years. The deficiency extended over practically the entire year, the only months in which the rainfall was in excess of the average being February, May, July and August, the excess in none of these months being great.

In some places the rainfall was the lowest that has been known for a very long period of years. The very low rainfall caused a severe drought in June and July, which was relieved to some extent by a greater than ordinary precipitation in August. In September the drought again became severe, and continued practically to the end of the year. The effect of the drought was felt most severely by the cities and towns deriving their supplies from mountain streams having comparatively small storage reservoirs, many of which became exhausted. Places supplied from lakes or reservoirs of large storage capacity had not been seriously affected up to the end of the year.

The result of the deficiency of rainfall and the exhaustion of many water supplies led to the introduction in many places of temporary supplies, acquired with the approval of the Board, under the provisions of chapter 25, section 35, of the Revised Laws.

The city of North Adams is supplied with water from a storage reservoir on Notch Brook and from Broad Brook, the watershed of the

latter stream being chiefly within the limits of the State of Vermont. In the latter part of the year the supplies became too small for the requirements of the city, and water was taken temporarily from tubular wells located in the city. The water of these wells is excessively hard and is evidently polluted, and upon a request from the board of health of the city for information as to its quality the Board advised as follows: —

. . . In the opinion of the Board the wells are not suitable sources from which to take water for drinking. The water supply ordinarily used by the city, obtained from Broad Brook and Notch Brook, is naturally of good quality for water supply purposes, but it is obvious that the quantity of water which these sources will furnish at their present development is insufficient for the requirements of the city in dry seasons, and unless the capacity of the works is enlarged a shortage is likely to be experienced more frequently in the future.

It is very important, in the opinion of the Board, that the city should provide for itself, as soon as practicable, an adequate supply of good water sufficient for its requirements at all times. . . .

Water Supply of the City of Lynn.

The water supply of the city of Lynn has for many years been drawn from four storage reservoirs and the Saugus River. The reservoirs furnish water of objectionable quality on account of its color, taste and odor, and the Saugus River, from which a large and increasing proportion of the supply is drawn, is very badly polluted by sewage. Plans for the improvement of the quality of the water have been under consideration for many years. In 1898 the public water board recommended the filtration of water in the manner carried on by the city of Lawrence, and in 1901 an act giving authority to the city of Lynn to take water from the Ipswich River also authorized the city to establish filtration works for the purification of its water supply.

One of the storage reservoirs then in existence was enlarged in the succeeding years, but nothing having been done to improve the quality of the water, or to protect the public health from the effect of a polluted supply, the Board in 1905 and again in 1906 reported to the Legislature the objectionable character of the Lynn water, and in the latter year an act was passed — chapter 509 of the Acts of the year 1906 — authorizing and directing the State Board of Health and the water board of the city of Lynn to investigate plans for enlarging and improving the water supply of the city. The results of this investigation were presented to the Legislature of 1907, and the following act was passed,

authorizing the city to make further investigations as to enlarging and improving its water supply and requiring that the construction of works be begun within one year from the date of the passage of that act, June 6, 1907: —

CHAPTER 479.

AN ACT TO AUTHORIZE THE CITY OF LYNN TO ENLARGE AND IMPROVE ITS WATER SUPPLY AND TO MAKE AN ADDITIONAL WATER LOAN.

Be it enacted, etc., as follows:

SECTION 1. The city of Lynn, for the purpose of enlarging and improving its water supply, is hereby authorized to issue from time to time bonds, notes or scrip, to be denominated on the face thereof, Lynn Water Loan, Act of 1907, to an amount not exceeding three hundred thousand dollars in addition to the amounts heretofore authorized by law to be issued by said city for similar purposes, which shall be payable at the expiration of periods not exceeding thirty years from the dates of issue, shall bear interest payable semi-annually at a rate not exceeding four per cent per annum, and shall be signed by the treasurer and countersigned by the board of water commissioners and by the mayor of the city. The city may sell such securities at public or private sale, or pledge the same for money borrowed for the purposes of this act, upon such terms and conditions as it may deem proper, provided that they shall not be sold for less than the par value thereof.

SECTION 2. The said city shall, at the time of authorizing said loan, provide for the payment thereof in such annual proportionate payments as will extinguish the same within the time prescribed by this act; and when a vote to that effect has been passed the amount required thereby shall without further vote be assessed by the assessors of the city in each year thereafter in the same manner in which other taxes are assessed until the debt incurred by the loan is extinguished. The city shall also raise annually by taxation a sum which, with the income derived from water rates, will be sufficient to pay the interest as it accrues on the securities issued under authority hereof.

SECTION 3. The proceeds of the sale or pledge of the said securities shall be used for necessary expenditures in connection with the enlargement and development of the water supply system of the city, and for the protection and improvement of the quality of the water; and the city may take, or acquire by purchase or otherwise, and hold for said purposes, any lands, easements or rights of way necessary for the purposes of this act, and for the purposes aforesaid may erect on any lands purchased, taken or held, proper dams, reservoirs, buildings, conduits, pipes, fixtures, filters or other structures necessary for the said purposes: *provided, however,* that no lands or rights therein shall be purchased, taken or used under this act without the consent of the state board of health, given after notice and a public hearing.

In carrying out the provisions of this act the city of Lynn shall have the

authority and be subject to all the duties, restrictions and liabilities set forth in chapter two hundred and eighteen of the acts of the year eighteen hundred and seventy-one and acts in amendment thereof or addition thereto.

SECTION 4. The construction of the works necessary for the enlargement and development of the said water supply and for protecting and improving the quality of the water shall be begun by said city, acting through its public water board, within one year, and shall be completed within three years after the passage of this act. The said works shall provide an adequate quantity of good water for all the requirements of the city, for the proper sanitary protection of such water and for the elimination and diversion from the sources of supply of all polluted waters, or for their purification or treatment, in such manner as will fully protect the public health.

SECTION 5. The construction of the said works shall be carried out by the public water board of said city, and the board is hereby further authorized and directed to make all necessary preliminary investigations and to prepare plans for the works, and for this purpose shall have power to employ engineering experts as to the sanitary protection, storage, and purification of water, and such other assistance as may be necessary. The preliminary investigations herein authorized shall include: an estimate of the cost of cleansing and making sanitary the watersheds of Pillings pond and Beaver Dam brook, so-called, in the town of Lynnfield, and of the cost of connecting the same with the present sources of water supply, together with an estimate of the amount of increase in the supply of water obtainable by the use of said pond and brook; an estimate of the cost of a conduit or pipe line to convey water from the Ipswich river or Martin's brook either separately or in connection with the water of Pillings pond and Beaver Dam brook into the present reservoirs of the city of Lynn, or for pumping water either from said Ipswich river or said Martin's brook into said Pillings pond or the present reservoirs by the plan deemed by said board to be most advisable; an estimate of the cost of cleaning or covering the bottom of Walden pond and of other ponds now used by the city of Lynn, or such parts of the bottom of Walden pond or the other ponds as have not so been treated; an investigation of the quality of the waters of all of the various sources and tributaries now used or available for the use of said city, with chemical and bacterial examinations thereof, at such points as may be agreed upon by the engineers and experts employed by the Lynn water board and the state board of health, including an investigation of all sources and causes of pollution or objection affecting the present or proposed sources of supply of the city of Lynn, the best methods of removing the same, and the estimated cost thereof.

SECTION 6. No act shall be done or liability incurred under this act in enlarging or improving the water supply of the city of Lynn, except in the making of surveys and investigations and the preparation of plans hereby authorized, until plans of the proposed conduits, reservoirs, pipe lines, except distribution pipes, filters or other works necessary to provide an adequate quantity of pure water for the city have been submitted to and

approved by the state board of health; and the said plans shall be presented to said board for approval not later than December thirty-first, nineteen hundred and seven, and shall be acted upon by said board on or before the third Wednesday in January in the year nineteen hundred and eight.

SECTION 7. This act shall take effect upon its passage. [*Approved June 6, 1907.*

Under the authority contained in section 5 of the above act, the public water board of the city of Lynn made a very thorough investigation of all available sources of water supply of the city, and prepared plans for enlarging and improving the supply, which under the provisions of section 6 of the above act were presented to the State Board of Health for its approval on Dec. 31, 1907, and were approved by the Board on Jan. 14, 1908.

Subsequently, in order to give the city opportunity for further investigation, the Legislature of 1908 passed an act — chapter 610 — entitled "An Act to extend the time within which the city of Lynn shall enlarge and improve its water supply," which was approved June 11, 1908, and under its authority the plans approved by the State Board of Health on Jan. 14, 1908, were recommitted to the public water board of the city of Lynn. The act is as follows: —

CHAPTER 610.

AN ACT TO EXTEND THE TIME WITHIN WHICH THE CITY OF LYNN SHALL ENLARGE AND IMPROVE ITS WATER SUPPLY.

Be it enacted, etc., as follows:

SECTION 1. The time within which the construction of the works for the enlargement and improvement of the water supply of the city of Lynn, required by the provisions of chapter four hundred and seventy-nine of the acts of the year nineteen hundred and seven, shall be begun by said city is hereby extended to the first day of January in the year nineteen hundred and nine, and the time within which said works shall be completed is hereby extended to the first day of January in the year nineteen hundred and eleven.

SECTION 2. The time for submission of plans for said proposed improvements to the state board of health by the public water board of the city of Lynn, as provided in section six of said chapter four hundred and seventy-nine, is hereby extended to the fifteenth day of October in the year nineteen hundred and eight. Said plans before such submission to the state board of health shall be submitted to the city council of Lynn for examination at a date not later than the fifteenth day of August in the year nineteen hundred and eight. If after the submission of said plans to the state board of health as aforesaid, but not later than the twentieth day of October in the year nineteen hundred and eight, the city council of Lynn shall request a

hearing on the matter of the acceptance of said plans, the state board of health shall, before finally passing upon them, grant a hearing thereon to the said city council at such time and place as the board shall fix. The state board of health shall act on said plans not later than the fifteenth day of November in the year nineteen hundred and eight. Any plans heretofore submitted to the state board of health by the public water board of the city of Lynn, and approved by the state board of health under the provisions of said chapter four hundred and seventy-nine, are hereby recommitted to the said public water board of the city of Lynn, but, except as said chapter four hundred and seventy-nine is specifically modified hereby, the city of Lynn shall proceed in accordance with its provisions.

SECTION 3. This act shall take effect upon its passage. [*Approved June 11, 1908.*

Under the provisions of this act further plans for enlarging and improving the water supply of the city of Lynn, and for protecting and preserving the quality of the water, were presented to the Board for approval on Oct. 15, 1908, and on Nov. 5, 1908, the Board gave a hearing to the city council of Lynn, upon its request, received before October 20, at which the city of Lynn was represented by the mayor, city solicitor, city engineer and members of the city council. After the hearing and consideration of the plans and information presented, the Board, on Nov. 12, 1908, voted to approve the plans. A copy of the communication sent to the city of Lynn relative thereto will be found in another part of this report.

Under the provisions of chapter 610 of the Acts of the year 1908, quoted above, the city of Lynn is required to begin the construction of the works Jan. 1, 1909, and to complete them on or before the first of January in the year 1911.

Water Supply of the City of Lawrence.

The construction of the new filter for the purification of the water supply of the city, begun in 1906, was completed and the water turned on for the first time on Nov. 5, 1907. The colder season of the year is not a favorable time in which to begin the operation of a new filter, but the work of the filter improved rapidly, and the water which was, in the beginning, wasted into the river, was found early in January to be satisfactory for use, and was turned on for the supply of the city. The supply has since been ample for all requirements of the city and the quality of the water satisfactory. The death-rate from typhoid fever has been low, as usual, and has differed but little from that of other years since the filtration of the water was begun.

Protection of the Purity of Public Water Supplies.

Under the authority of chapter 75, section 113, of the Revised Laws, authorizing the State Board of Health to make rules and regulations for the sanitary protection of public water supplies, the Board during the year 1908 established rules and regulations for the protection of the water supplies of Andover (Haggett's Pond), Holyoke (Manhan River only) and the Turners Falls Fire District in the town of Montague (Lake Pleasant).

The cities and towns in the State in which such rules are in force are the following: —

Abington and Rockland.
Amherst.
Andover.
Attleborough.
Brockton and Whitman.
Cambridge.
Chicopee.
Danvers and Middleton.
Easthampton.
Fall River.
Falmouth.
Fitchburg.
Greenfield.
Haverhill.
Holyoke.
Lincoln and Concord.
Lynn.
Marlborough.
Maynard.
Montague.
Northampton.
Northborough.
Norwood.
Peabody.
Pittsfield.
Plymouth.
Randolph and Holbrook.
Rockport.
Salem and Beverly.
Springfield and Ludlow.
Taunton.
Wakefield.
Westfield.
West Springfield.
Weymouth.
Worcester.

EXAMINATION OF SEWER OUTLETS.

Nearly all the main sewer outlets of the State have been examined during the year by the chief engineer of the Board or his assistants. There are at the present time 116 cities and towns having complete or partially complete systems of sewerage. Of these, 26 are connected with the north and south metropolitan sewerage systems respectively, and the sewage of these districts and of the city of Boston is discharged into Boston harbor at three separate outlets.

In addition to the metropolitan sewers, the sewers of 14 other cities and towns discharge their sewage either directly into the sea or into adjacent streams or tidal estuaries.

The main sewerage system for the city of Salem and town of Peabody was completed on Dec. 31, 1906. When the connections are made all

the sewage of the city of Salem and town of Peabody, except such as may overflow from combined sewers in Salem during storms, together with objectionable manufacturing wastes, can be conveyed to the new main sewer outlet at Great Haste in Salem harbor. The system has been constructed in general accordance with the scheme recommended by the State Board of Health in 1896, after an investigation under an act of the Legislature of 1895.

The completion of this main sewerage system and of a sewerage system in the town of Peabody now makes it practicable to remove the sewage and manufacturing wastes which have long made the North River in Salem and Peabody a notorious nuisance.

Of the sewer outlets discharging into the sea the most objectionable at the present time are those of the cities of Lynn and New Bedford. The sewage of the city of Lynn is discharged at the end of a long wharf into a small branch of the harbor channel, at all stages of the tide. There are extensive flats in the neighborhood of the outlet which are exposed at low tide, and owing to the fact that the currents in the harbor are weak, the direction in which the sewage flows is influenced mostly by the wind. With easterly and southerly winds, and in calm weather, the sewage is carried upon the neighboring flats and shores, and there are deposits of sewage sludge along the shores and in the small bays and inlets about the upper end of the harbor, carried there from the sewer outlet by the wind and tide. The odor from the flats and shores is offensive and the conditions are very objectionable.

In response to a complaint from the board of health of the city of Lynn as to the pollution of shellfish in Lynn harbor, used for food, the Board caused an investigation to be made, the result of which showed the presence of bacteria characteristic of sewage in shellfish collected in all parts of the harbor and in the estuaries of the Saugus and Pines rivers. On Nov. 5, 1908, the Board requested the Board of Commissioners on Inland Fisheries and Game to —

> . . . prohibit the taking of any clams from the waters or flats of Lynn harbor or its tributaries, including the Saugus and Pines rivers, north of a line drawn from the Pines Hotel at the Point of Pines to Bass Point, the southernmost point of the peninsula of Nahant. . . .

The sewage of the city of New Bedford is discharged from 41 sewer outlets into the New Bedford harbor along the shore on the water front of the city and into the head of Clark's Cove at its southerly end. Many of the sewers along the water front discharge into docks or close to the shores, where there is little or no current to remove the sewage, and deposits of sludge have formed about many of the sewer outlets which

cause serious nuisances along the shore. The most serious nuisance, however, exists at Clark's Cove, into which about one-third of the sewage of the city is discharged. The prevailing winds during the summer season are usually from the southwest, and the sewage is driven to the shore, and much sewage matter can be found at all times during the summer season scattered over the beach or mingled with seaweed and other débris about the upper end of the cove. The region about the head of the cove is very densely populated and the beach about it is used as a playground by large numbers of children. There can be no question of the danger involved to the public health in these unsanitary conditions.

Of the remaining cities and towns having sewerage systems, 31 discharge their sewage untreated into the Merrimack or Connecticut rivers and 16 into other rivers in the State, while in 28 cities and towns there are works for the purification of the sewage before it is discharged into the streams.

In general the sewage-disposal works of the various cities and towns of the State are well managed and efficient, but in a few cases the results of the operation of such works are not satisfactory, either through lack of sufficient capacity or neglect, and more or less unpurified or partially purified sewage is allowed to escape from them into neighboring streams. The disposal works of the town of Lenox is one of the most objectionable in these respects, and during much of the past year most of the sewage of the town of Lenox was being discharged directly into the Housatonic River through a pipe discharging beneath the surface of the water a short distance below the railroad station at Lenox.

Pollution of Streams.

The extremely dry season of 1908 has emphasized the effect of the pollution of streams. Numerous samples of water have been collected from the rivers of the State, at various points, during the period from June to November, and at some places throughout the year, the points selected being in many cases the same as those at which examinations have been made in previous years.

Pollution of Neponset River.

A considerable improvement in the condition of the Neponset River was noticeable during the year, as compared with previous years. This result was due in part to the removal of sewage and manufacturing wastes from the stream, in accordance with the provisions of laws designed to prevent its pollution, but also undoubtedly in some degree to the fact that several of the factories have been doing comparatively

little work during much of the year on account of the financial depression, with a consequent diminution of the amount of manufacturing wastes discharged into the stream.

A sewerage system and purification works have been constructed by the town of Norwood which were completed at the end of the year. It will be practicable during the coming year to connect many of the factories which now discharge their sewage into tributaries of the Neponset River and into the main stream in that town with the sewerage system, and thus remove many of the sources of pollution of the stream for which it has hitherto been impracticable to find a proper outlet.

Availing themselves of a provision of the act of 1906, authorizing consultation with the State Board of Health, the owners of factories have held numerous consultations with the officers of the Board during the past year, and experiments have been made at several of the mills, the results of which have furnished information as to methods by which the wastes can be purified. At a few of the smaller factories purification works have been built or are under construction, and plans for purifying the wastes of most of the remaining factories have been approved by the Board. There appears to be no necessity for delay in the construction of works for the purification of wastes at most of the factories when the weather again becomes favorable for such work.

Pollution of the Assabet River.

The Assabet River has been very offensive below the sewage-disposal area of the town of Westborough during much of the drier portion of 1908, by reason of the discharge of unpurified sewage into the river at that area. The river has also been offensive below Hudson and below Maynard, on account of the discharge of sewage and manufacturing wastes into the stream at those places.

The purification works for the treatment of the sewage of the town of Westborough were constructed originally without engineering supervision, and were inadequate for the purification of the sewage, the result being that the sewage was discharged into the Assabet River until, owing to complaints and suits at law from citizens in the valley below, the town reconstructed its sewage-disposal works in the year 1899.

On Dec. 20, 1899, the sewer commissioners of Westborough applied to the Board for its opinion as to the efficiency of the filters, and the Board, after observing for a time the operation of the filters, replied to their communication on March 6, 1900, as follows: —

The State Board of Health has considered your application for advice with reference to the efficiency of the reconstructed main sewer and filter

beds for the removal and purification of the sewage of the town of Westborough, and has caused the works to be examined by one of its engineers and samples of the sewage and effluent to be analyzed.

A comparison of the recent measurement of the quantity flowing in the main sewer with the quantity flowing under similar conditions last year indicates that the leakage has been very greatly reduced. The new filter beds are probably of sufficient area to purify the sewage flowing from the town under present conditions; and, when the remaining filter bed is completed, according to the plans, the filters will be of sufficient capacity to provide for a considerable increase in the quantity of sewage flowing from the town in the future, when the system becomes more generally used in the town.

The results of the analyses of the sewage and effluent show that the sewage is being efficiently purified by these filters at the present time; and, in the opinion of the Board, the filters will, if enlarged when necessary, and properly operated, purify efficiently the sewage of Westborough, so that the effluent will not have a noticeable effect upon the appearance or condition of the Assabet River.

The new works were constructed in general accordance with recommendations of the State Board of Health, though the area of filters constructed was less than recommended by the Board.

While the reconstructed filters were probably adequate for the purification of all of the sewage of the town until quite recently, they have never received the care which such works require, and the sewage has been allowed to flow upon the filters in one place for many weeks at a time. In consequence of this improper method of operation the sewage has found its way through a limited area of the filters in an unpurified or partially purified state, and during the past year, when there was but little flow in the Assabet River opposite the filters to dilute the sewage, the result was the gross pollution of the stream for a long distance below the filters. Farther down the stream, in the town of Northborough, the river is joined by several tributaries, and it does not appear that its condition has been objectionable below that point until after passing Hudson.

The town of Hudson has a sewerage system, including a disposal works of several acres of filter beds excellently adapted for the purification of sewage by intermittent filtration. An examination at the end of the year showed that the filters had not been levelled after ridging in the previous winter, that only a part of the area had been used, and that many of the filters were covered with enormous growths of weeds, having received practically no attention throughout the year. It has also been found that sewage and manufacturing wastes were being discharged directly into the river, which was badly polluted below the town.

At Maynard the river is polluted to some extent by sewage from mills and dwelling houses in the town, but chiefly by manufacturing wastes, including wastes from the scouring of wool and washing of cloth in the large mills located on the stream at that place.

Pollution of the North Branch of the Nashua River.

In the report of last year the following statement was made relative to the pollution of the north branch of the Nashua River: —

The health of the inhabitants in the valley of the north branch of the Nashua River below the city of Fitchburg is very seriously threatened by the offensive conditions resulting from the discharge of sewage and manufacturing waste into the stream and its tributaries, chiefly in the city of Fitchburg.

In the year 1901 the city of Fitchburg secured legislation (chapter 354 of the Acts of the year 1901) to enable it to construct a system of sewage disposal, and then caused a thorough investigation to be made and plans to be prepared for the collection and final purification of all of the sewage of the city. These plans were presented to the State Board of Health for its approval, under the provisions of the act above mentioned, on Dec. 2, 1903, and a hearing was given by the Board to all persons interested on Dec. 17, 1903.

The sewers of the city of Fitchburg are built upon the combined plan, and receive both sewage and rain water, and the plans presented for the consideration of the Board made provision both for the construction of works for the purification of the sewage and for the separation of the sewage from the storm water in all of the area of the city then served by combined sewers; but, as it was urged by the city authorities that it would be difficult for the city, on account of the expense, to do all of the work necessary immediately, it was proposed to construct the sewage-disposal works and to separate the sewage from the storm water only in a portion of the city in the beginning, and to carry out the separation in the remaining portions by a gradual process of construction that would finally result in the complete removal of unpurified sewage and manufacturing wastes from the river. In order to give the city ample time to complete the separation of the sewage from the storm water, the date determined upon for the final completion of that work was, after conference with the city authorities, Jan. 1, 1915. By this arrangement the city would have had about eleven years in which to rebuild its sewerage system to the extent necessary to prevent the further discharge of sewage into the north branch of the Nashua River; but, though four years have passed since the plans were approved, the construction of the proposed sewage-purification works has not been begun, and there is no evidence of any intention on the part of the city to carry out any portion of the plans for which the city authorities secured the approval of this Board under the circumstances above described.

Sewage and manufacturing waste from the town of Leominster are discharged into one of the tributaries of the Nashua River which enters that stream a short distance below Fitchburg. Plans for the purification of the sewage of the town of Leominster also have been prepared by the authorities of that town and approved by this Board; but the construction of a sewage-disposal system has been postponed, apparently to await action by the Fitchburg authorities, though the plans received the approval of the Board nearly four years ago.

In view of the present very offensive condition of the river and the danger to the public health in this valley from its continued pollution, the Board, as required by law, brings the matter to the attention of the Legislature for such action as it may deem necessary.

The condition of the river during the year 1908 has been more objectionable than in any previous year, and is the worst of any of the rivers of the State, with the exception of those where action has already been taken for the purification or removal of polluting substances. The committee on drainage of the Legislature of 1908, to which the report quoted was referred, gave several hearings upon the matter early in 1908, and subsequently, upon the assurance of the mayor of the city that he would bring the matter to the attention of the city council, no legislation was deemed necessary.

On October 20, by invitation of the mayor, the chairman and the engineer of the Board visited Fitchburg and conferred with the city council and others relative to means of preventing the pollution of the stream. Subsequently it appears that the matter was taken up by the city government and a special committee appointed for its consideration. Concerning the action of this committee the mayor (for 1908) states, under date of Jan. 4, 1909: —

On Tuesday, the twenty-ninth day of December, the last meeting of the city council for the year, this committee presented a report recommending to the city council that the mayor be authorized to petition the Legislature this year for authority to establish an administrative board and have charge of the sewer system and the construction of a trunk sewer, accompanying their report with a bill to be presented for that purpose. The recommendation was adopted by the board of aldermen and sent down for concurrence to the lower branch, where it was laid upon the table, and there remained when the government of 1908 expired.

It is very important, in the opinion of the Board, that decisive action be taken with as little delay as possible, to prevent the continued use of the north branch of the Nashua River or its tributaries as a place of sewage disposal.

Lawrence Experiment Station.

During the year sixty-one filters have been in operation at the Lawrence Experiment Station studying various questions in connection with the purification of sewage and water. Studies of methods of distributing sewage upon trickling filters, reported upon last year, have been continued, and investigations have been made to determine what effect different materials that can be used in the construction of filters have upon the improvement of such distribution, as given by sprinklers, etc. In continuation of this investigation three new filters have been started, to determine the degree of purification of sewage accomplished by sprinkling filters upon which the distribution is practically uniform, as compared with filters upon which the sewage is applied very unequally, to different portions of the surface. Exhaustive studies have been made to determine the efficiency and practicability of the sterilization of sewage and sewage effluents by chlorine in its various forms. In this connection some of the filters have been operated with sewage sterilized with this reagent, and the effluents of others have been treated with chemicals before their application to secondary filters.

Various investigations have been made during the year with filters operated with the wastes from tanneries, shoddy mills, yeast factories, glue works, etc. Studies have also been made upon the volume and composition of the gases formed by the fermentation of different sludges and sediments from sewage and sewage filters, and experiments upon the destructive distillation of sewage sludge for the production of illuminating gas have been made. These experiments, preliminary as yet, have much promise and seem to show that large volumes of gas suitable for lighting and heating can be obtained from the destructive distillation of such sludge. A number of water filters have been kept in operation to show the practicability of high rates when treating polluted waters, and in this connection an extensive investigation has been made of a large mechanical filter plant in one of the mills, and of the value of ferric sulphate as a substitute for sulphate of alumina in such rapid mechanical filtration. In the bacteriological laboratory many especial studies of methods for bacteriological analysis have been made, particular attention having been paid to the development of methods which may give a more prompt determination of the quality of the water or the efficiency of a water filter. In the chemical laboratory various studies have been made with a view of finding a method which will give the quickest and surest indication of the degree of stability of the effluents of sewage filters.

Local Outbreaks of Infective Disease.

During the year an unusually extensive milk-borne outbreak of typhoid fever was investigated and reported in the official "Bulletin" of the Board. The details of this and of other outbreaks appear in the Supplement.

Food and Drug Inspection.

The number of samples of foods and drugs collected and examined during the year ended Nov. 30, 1908, was 6,609, and the total number since the work was begun in 1882 has now reached 183,283.

During the year 433 prosecutions were made in the various courts of the Commonwealth, bringing the total number to 3,276. The details are presented in the Supplement.

Inspection of Liquors.

The work of the Board in connection with the duties of the office of inspector and assayer of liquors, transferred to the Board in 1902, is reported upon in the Supplement.

Inspection of Dairies.

During the twelve months covered by this report 2,231 dairies were inspected by the veterinarian of the Board. Of this number, 18 are situated in other States, but their product is shipped into this State for public sale.

Of the total number of Massachusetts dairies visited, a few more than half (1,185) were free from objectionable conditions, — a great improvement over the previous year, when only rather more than a third of the dairies visited could be thus classified.

To the owners of the 1,028 dairies which showed insanitary conditions, letters were sent calling attention to a total of 4,165 objectionable features. The details will be found in the Supplement.

Reports upon Health of Towns, Fatality of Certain Diseases, Official Returns of Deaths in Cities and Large Towns, General Health of the State, the Production, Distribution and Use of Diphtheria Antitoxin and Vaccine, and upon Bacteriological Diagnosis are presented in the Supplement.

Routine Work of the Board.

Statistical Table for the Year ended Nov. 30, 1908.

Whole number of samples of food and drugs examined, . . .	6,609
Samples of milk examined (included in the foregoing), . . .	3,934

Whole number of samples of food and drugs examined since beginning of work in 1883,	183,283
Whole number of samples of milk examined since beginning of work in 1883,	100,997
Number of prosecutions against offenders during the year,	433
Number of convictions during the year,	386
Amount of fines imposed,	$8,300.30
Number of dairies examined,	2,231
Number of packages of antitoxin of 1,500 units each issued to cities and towns,	94,645
Number of tubes of vaccine issued to cities and towns,	48,768
Number of bacterial cultures made for the diagnosis of diphtheria in cities and towns,	4,089
Number of examinations made for diagnosis of tuberculosis,	1,891
Number of examinations of blood made for diagnosis of malarial infection,	40
Number of examinations of blood made for the diagnosis of typhoid fever,	934
Number of notices of cases of infectious diseases received and recorded under the provisions of chapter 75, section 52, Revised Laws,	50,236

Force employed in general work of Board at central office, State House: —	
Secretary,	1
Assistant to the secretary,	1
Clerks,	6
Messengers,	2
Sanitary inspector of dairies,	1
Total,	11

Force employed for food and drug inspection: —	
Chemists and assistants,	4
Inspectors,	4
Total,	8

Force employed at laboratory, Forest Hills: —	
Pathologist,	1
Assistants,	6
Total,	7

Under the Provisions of Sections 112 to 118 of Chapter 75, Revised Laws.

Applications for advice from cities, towns and others: —

Relating to water supply,	92
Relating to ice supply,	6
Relating to sewerage and drainage,	30
Relating to pollution of streams,	4
Miscellaneous,	2
Total,	134

Number of samples of water, ice and sewage examined chemically and microscopically at the laboratory, Room 502, State House,	6,267
Number of samples of water, sewage, ice, etc., examined chemically and bacterially at Lawrence Experiment Station,	2,291
Number of samples of water, sewage and ice examined bacterially,	6,469
Number of samples of sand examined chemically and mechanically,	112
Number of samples of sand examined chemically only,	198
Number of samples of sand examined mechanically only,	40
Number of samples of shellfish examined bacterially,	170
Total number of samples examined,	15,547

Force employed at central office: —		
Chief engineer,	1	
Assistant engineers,	9	
Stenographers and clerks,	4	
Messenger,	1	
		15
Force employed at laboratory, Room 502, State House: —		
Chemist,	1	
Assistant chemists,	6	
Biologist,	1	
Stenographer,	1	
		9
Force employed at Lawrence Experiment Station: —		
Assistant chemists,	2	
Bacteriologists,	2	
Other assistants and laborers,	3	
		7
Total ordinary force,		31

The number of applications for advice under the provisions of the acts relating to water supply and sewerage, received since July, 1886, when these acts first went into operation, is as follows:—

1886,	8	1899,	79
1887,	22	1900,	104
1888,	28	1901,	105
1889,	38	1902,	93
1890,	23	1903,	129
1891,	53	1904,	125
1892,	56	1905,	105
1893,	51	1906,	130
1894,	53	1907,	125
1895,	52	1908,	134
1896,	65		
1897,	59	Total,	1,712
1898,	75		

APPROPRIATIONS.

The appropriations for the year ended Nov. 30, 1908, as recommended by the Board in the annual estimates made under the provisions of chapter 6, section 26, of the Revised Laws, were as follows:—

For the general expenses of the Board,	$20,000 00
For the inspection of food and drugs,	14,500 00
For the production and distribution of antitoxin and vaccine,	15,000 00
For the purity of inland waters,	36,000 00
For the examination of sewer outlets and Neponset River,	12,000 00
For printing the annual report,	4,000 00
State inspectors of health,	30,000 00
Total,	$131,500 00

EXPENDITURES.

The expenditures under the different appropriations for the year ended Nov. 30, 1908, were as follows:—

General Expenditures.

Appropriation,	$20,000 00
Salaries,	$11,812 05
Travelling expenses,	1,500 60
Amount brought forward,	$13,312 65

Amount carried forward,	$13,312 65
Stationery,	267 87
Printing,	2,631 02
Books, subscriptions and binding,	507 98
Advertising,	44 00
Express charges,	35 17
Extra services,	286 51
Messenger,	171 97
Postage and postal orders,	1,395 33
Telephone and telegraph messages,	128 08
Typewriting supplies,	78 73
Special investigations,	26 91
Sundry office supplies,	410 47
Laboratory supplies,	321 57
Miscellaneous,	12 31
Total,	$19,630 57

Expenditures for the Production and Distribution of Antitoxin and Vaccine for the Year ended Nov. 30, 1908.

Appropriation,	$15,000 00
Salaries,	$6,468 33
Printing,	203 01
Stationery,	39 15
Laboratory supplies,	2,097 33
Laboratory construction,	222 89
Rent of laboratory and stable,	1,490 69
Express,	34 23
Travelling,	7 60
Purchase of animals,	908 43
Board of horses,	2,256 01
Services of veterinary,	24 50
Food for animals,	505 20
Rental of telephone, messages and postage,	162 25
Extra services,	76 80
Ice,	39 08
Gas, electric lighting, heating and water,	310 23
Miscellaneous,	154 25
Total,	$14,999 98

Expenditures under the Provisions of the Food and Drug Acts for the Year ended Nov. 30, 1908.

Appropriation,	$14,500 00
Salaries of analysts,	$5,833 33
Salaries of inspectors,	4,628 09
Travelling expenses and purchase of samples,	2,207 72
Apparatus and chemicals,	934 69
Printing,	142 10
Services, cleaning laboratory,	106 00
Express, telephone and telegraph messages,	21 87
Sundry laboratory supplies,	114 22
Books and maps,	41 70
Extra services,	352 50
Advertising,	63 22
Miscellaneous,	19 52
Total,	$14,464 96

For carrying out the Provisions of the Act to protect the Purity of Inland Waters, and to require Consultation with the State Board of Health regarding the Establishment of Systems of Water Supply, Drainage and Sewerage.

Appropriation for the year ended Nov. 30, 1908,	$36,000 00
Salaries, including wages of laborers at Lawrence Experiment Station,	$27,334 55
Apparatus and materials,	2,579 83
Rent of Lawrence Experiment Station,	150 00
Repairs and maintenance, Lawrence Experiment Station,	469 35
Travelling expenses,	1,950 96
Express charges,	1,522 15
Books and binding,	247 90
Maps and blue prints,	869 35
Stationery, drawing materials and typewriting supplies,	506 16
Telephone and telegraph messages, and postage,	41 96
Extra services,	81 57
Services, collecting samples and reading gauges,	33 85
Miscellaneous,	212 10
Total,	$35,999 73

Amount carried forward,	$13,312 65
Stationery,	267 87
Printing,	2,631 02
Books, subscriptions and binding,	507 98
Advertising,	44 00
Express charges,	35 17
Extra services,	286 51
Messenger,	171 97
Postage and postal orders,	1,395 33
Telephone and telegraph messages,	128 08
Typewriting supplies,	78 73
Special investigations,	26 91
Sundry office supplies,	410 47
Laboratory supplies,	321 57
Miscellaneous,	12 31
Total,	$19,630 57

Expenditures for the Production and Distribution of Antitoxin and Vaccine for the Year ended Nov. 30, 1908.

Appropriation,	$15,000 00
Salaries,	$6,468 33
Printing,	203 01
Stationery,	39 15
Laboratory supplies,	2,097 33
Laboratory construction,	222 89
Rent of laboratory and stable,	1,490 69
Express,	34 23
Travelling,	7 60
Purchase of animals,	908 43
Board of horses,	2,256 01
Services of veterinary,	24 50
Food for animals,	505 20
Rental of telephone, messages and postage,	162 25
Extra services,	76 80
Ice,	39 08
Gas, electric lighting, heating and water,	310 23
Miscellaneous,	154 25
Total,	$14,999 98

Expenditures under the Provisions of the Food and Drug Acts for the Year ended Nov. 30, 1908.

Appropriation,	$14,500 00

Salaries of analysts,	$5,833 33
Salaries of inspectors,	4,628 09
Travelling expenses and purchase of samples,	2,207 72
Apparatus and chemicals,	934 69
Printing,	142 10
Services, cleaning laboratory,	106 00
Express, telephone and telegraph messages,	21 87
Sundry laboratory supplies,	114 22
Books and maps,	41 70
Extra services,	352 50
Advertising,	63 22
Miscellaneous,	19 52
Total,	$14,464 96

For carrying out the Provisions of the Act to protect the Purity of Inland Waters, and to require Consultation with the State Board of Health regarding the Establishment of Systems of Water Supply, Drainage and Sewerage.

Appropriation for the year ended Nov. 30, 1908,	$36,000 00

Salaries, including wages of laborers at Lawrence Experiment Station,	$27,334 55
Apparatus and materials,	2,579 83
Rent of Lawrence Experiment Station,	150 00
Repairs and maintenance, Lawrence Experiment Station,	469 35
Travelling expenses,	1,950 96
Express charges,	1,522 15
Books and binding,	247 90
Maps and blue prints,	869 35
Stationery, drawing materials and typewriting supplies,	506 16
Telephone and telegraph messages, and postage,	41 96
Extra services,	81 57
Services, collecting samples and reading gauges,	33 85
Miscellaneous,	212 10
Total,	$35,999 73

Amount carried forward,	$13,312 65
Stationery,	267 87
Printing,	2,631 02
Books, subscriptions and binding,	507 98
Advertising,	44 00
Express charges,	35 17
Extra services,	286 51
Messenger,	171 97
Postage and postal orders,	1,395 33
Telephone and telegraph messages,	128 08
Typewriting supplies,	78 73
Special investigations,	26 91
Sundry office supplies,	410 47
Laboratory supplies,	321 57
Miscellaneous,	12 31
Total,	$19,630 57

Expenditures for the Production and Distribution of Antitoxin and Vaccine for the Year ended Nov. 30, 1908.

Appropriation,	$15,000 00
Salaries,	$6,468 33
Printing,	203 01
Stationery,	39 15
Laboratory supplies,	2,097 33
Laboratory construction,	222 89
Rent of laboratory and stable,	1,490 69
Express,	34 23
Travelling,	7 60
Purchase of animals,	908 43
Board of horses,	2,256 01
Services of veterinary,	24 50
Food for animals,	505 20
Rental of telephone, messages and postage,	162 25
Extra services,	76 80
Ice,	39 08
Gas, electric lighting, heating and water,	310 23
Miscellaneous,	154 25
Total,	$14,999 98

Expenditures under the Provisions of the Food and Drug Acts for the Year ended Nov. 30, 1908.

Appropriation,	$14,500 00
Salaries of analysts,	$5,833 33
Salaries of inspectors,	4,628 09
Travelling expenses and purchase of samples,	2,207 72
Apparatus and chemicals,	934 69
Printing,	142 10
Services, cleaning laboratory,	106 00
Express, telephone and telegraph messages,	21 87
Sundry laboratory supplies,	114 22
Books and maps,	41 70
Extra services,	352 50
Advertising,	63 22
Miscellaneous,	19 52
Total,	$14,464 96

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Appropriation for the year ended Nov. 30, 1908,	$36,000 00
Salaries, including wages of laborers at Lawrence Experiment Station,	$27,334 55
Apparatus and materials,	2,579 83
Rent of Lawrence Experiment Station,	150 00
Repairs and maintenance, Lawrence Experiment Station,	469 35
Travelling expenses,	1,950 96
Express charges,	1,522 15
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For carrying out the Provisions of the Act to protect the Purity of Inland Waters, and to require Consultation with the State Board of Health regarding the Establishment of Systems of Water Supply, Drainage and Sewerage.

Appropriation for the year ended Nov. 30, 1908,	$36,000 00
Salaries, including wages of laborers at Lawrence Experiment Station,	$27,334 55
Apparatus and materials,	2,579 83
Rent of Lawrence Experiment Station,	150 00
Repairs and maintenance, Lawrence Experiment Station,	469 35
Travelling expenses,	1,950 96
Express charges,	1,522 15
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Special investigations,	26 91
Sundry office supplies,	410 47
Laboratory supplies,	321 57
Miscellaneous,	12 31
Total,	$19,630 57

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Appropriation,	$15,000 00
Salaries,	$6,468 33
Printing,	203 01
Stationery,	39 15
Laboratory supplies,	2,097 33
Laboratory construction,	222 89
Rent of laboratory and stable,	1,490 69
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Extra services,	76 80
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Gas, electric lighting, heating and water,	310 23
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Salaries of inspectors,	4,628 09
Travelling expenses and purchase of samples,	2,207 72
Apparatus and chemicals,	934 69
Printing,	142 10
Services, cleaning laboratory,	106 00
Express, telephone and telegraph messages,	21 87
Sundry laboratory supplies,	114 22
Books and maps,	41 70
Extra services,	352 50
Advertising,	63 22
Miscellaneous,	19 52
Total,	$14,464 96

For carrying out the Provisions of the Act to protect the Purity of Inland Waters, and to require Consultation with the State Board of Health regarding the Establishment of Systems of Water Supply, Drainage and Sewerage.

Appropriation for the year ended Nov. 30, 1908,	$36,000 00
Salaries, including wages of laborers at Lawrence Experiment Station,	$27,334 55
Apparatus and materials,	2,579 83
Rent of Lawrence Experiment Station,	150 00
Repairs and maintenance, Lawrence Experiment Station,	469 35
Travelling expenses,	1,950 96
Express charges,	1,522 15
Books and binding,	247 90
Maps and blue prints,	869 35
Stationery, drawing materials and typewriting supplies,	506 16
Telephone and telegraph messages, and postage,	41 96
Extra services,	81 57
Services, collecting samples and reading gauges,	33 85
Miscellaneous,	212 10
Total,	$35,999 73

For the Examination of Sewer Outlets, under the provisions of Section 4 of Chapter 75 of the Revised Laws.

Appropriation for the year ended Nov. 30, 1908,	$12,000 00
Salaries, including wages of laborers at Lawrence Experiment Station,	$7,577 04
Apparatus and materials,	957 07
Repairs and maintenance, Lawrence Experiment Station,	443 35
Travelling expenses,	2,215 02
Express,	75 13
Telephone and telegraph messages and postage,	56 78
Extra services,	87 83
Services, collecting samples and reading gauges,	53 00
Books, maps and blue prints,	293 19
Stationery, drawing materials and typewriting supplies,	113 02
Miscellaneous,	128 33
Total,	$11,999 76

Expenditures under the Provisions of the Act to provide for the Establishment of Health Districts and the Appointment of Inspectors of Health.

Appropriation,	$30,000 00
Salaries,	$25,278 59
Travelling expenses,	2,479 93
Express,	13 15
Printing,	485 38
Books and stationery,	354 52
Postage,	243 32
Typewriter supplies and typewriting,	83 35
Office supplies,	23 35
Telephone and telegraph messages,	33 53
Extra services,	76 83
Maps and blue prints,	4 83
Miscellaneous,	13 53
Total,	$29,090 31

HENRY P. WALCOTT.
JULIAN A. MEAD.
HIRAM F. MILLS.
GERARD C. TOBEY.
JAMES W. HULL.
CHARLES H. PORTER.
ROBERT W. LOVETT.

SUPPLEMENT.

WATER SUPPLY AND SEWERAGE.

ADVICE TO CITIES, TOWNS AND PERSONS.

ADVICE TO CITIES, TOWNS AND PERSONS.

Under the provisions of the Revised Laws (chapter 75, section 117), the State Board of Health is required to

consult with and advise the authorities of cities and towns and persons having, or about to have, systems of water supply, drainage or sewerage, as to the most appropriate source of water supply, and the best method of assuring its purity or as to the best method of disposing of their drainage or sewage with reference to the existing and future needs of other cities, towns or persons which may be affected thereby. It shall also consult with and advise persons engaged or intending to engage in any manufacturing or other business whose drainage or sewage may tend to pollute any inland water as to the best method of preventing such pollution, and it may conduct experiments to determine the best methods of the purification or disposal of drainage or sewage. No person shall be required to bear the expense of such consultation, advice or experiments. Cities, towns and persons shall submit to said board for its advice their proposed system of water supply or of the disposal of drainage or sewage, and all petitions to the general court for authority to introduce a system of water supply, drainage or sewerage shall be accompanied by a copy of the recommendation and advice of said board thereon.

During the year 1908 the Board has given its advice to the following cities, towns and persons who have applied for such advice under the provisions of this act or under special acts relating to water supply and sewerage.

Official communications were made during the year under the provisions of acts relating to water supply and to sources of ice supply, as follows: —

WATER SUPPLY.

Abington and Rockland.
Amesbury (well).
Andover.
Athol.
Avon.
Bedford (two).
Belchertown.
Boston (Clifton Manufacturing Company).
Braintree (well of A. H. Sanford).
Brockton.
Brookfield (East Brookfield).
Chelmsford (North Chelmsford Fire District).
Chicopee (Fairview).
Cohasset.
Dudley (J. Prescott).
Easthampton.

Easton (North Easton Village District).
Everett (well).
Fitchburg (three).
Framingham (two).
Franklin.
Gardner (State Colony for the Insane).
Greenfield.
Hadley (well in North Hadley).
Hamilton (well at Hamilton Park) (two).
Hanson (Hanson Manufacturing Company).
Haverhill (New England Deaconess Association).
Hingham (C. H. Leary).
Holyoke.
Holyoke (American Thread Company).
Hyde Park (Becker-Brainard Milling Machine Company).
Lawrence.
Lenox (two).
Lynn (two).
Lynn (well in Meadow Park).
Lynn (Y. M. C. A.).
Manchester.
Marblehead.
Medway.
Middlefield.
Milton (well of Thomas Craig).
Montague (Turners Falls Fire District).
Montague (Lake Pleasant Water Supply District).
Newburyport (three).
Newton.
North Adams.
North Adams (wells).
Northbridge (well at almshouse).
Northfield (East Northfield).
North Reading (town well).
North Reading (well at Boston & Maine Railroad cottage).
North Reading (well of J. B. McLane).
Palmer.
Palmer (well at almshouse).
Palmer (Thorndike Manufacturing Company).
Palmer (Boston Duck Company).
Palmer (well in Bondsville).
Pepperell.
Pittsfield (two).
Plymouth (Elder Brewster Spring).
Rowley (well of W. C. Foster's Sons).
Sandwich (Battery A, M. V. M.).
Shelburne (Shelburne Falls Fire District).
Sherborn (Reformatory Prison for Women).
Somerset (wells).
Somerset (spring).
Southbridge.
Springfield (two).
Sterling.
Wakefield (Heywood Brothers & Wakefield Company).
Ware (Pine Grove Mineral Spring).
Wareham (Wareham Fire District).
Wellesley.
West Brookfield.
West Springfield (two).
Winchester.
Woburn.
Wrentham (State School) (three).
Yarmouth, Dennis, Harwich and Chatham.

Ice Supply.

Acushnet.
Concord.
Holyoke.
Lexington.
West Springfield.

Official communications were made during the year under general and special acts relating to sewerage and sewage disposal, as follows: —

Attleborough.
Canton (Draper Bros. & Co.).
Chelmsford (North Chelmsford) (two).
Clinton.
Easthampton.
Grafton (Grafton Colony for the Insane).
Hyde Park (Tileston & Hollingsworth Company).
Lowell (two).
Ludlow.
Medfield (Medfield Insane Asylum).
Milford and Hopedale.
Monson.
Monson (Massachusetts Hospital for Epileptics).
North Andover.
North Attleborough.
Rutland (State Sanatorium).
Stoughton (Stoughton Mills) (two).
Taunton (Taunton Insane Hospital) (two).
Templeton (Templeton Inn).
Tewksbury (State Hospital) (two).
Wakefield (Heywood Brothers & Wakefield Company).
Walpole (Lewis Manufacturing Company).
Walpole (F. W. Bird & Son).
Wellesley (Wellesley College).

MISCELLANEOUS.

Lynn (taking of shellfish).
Malden (pollution of Malden River).
Sherborn (Jacob Lander).

WATER SUPPLY.

The following is the substance of the action of the Board during the year in reply to applications for advice relative to water supply: —

ABINGTON AND ROCKLAND.

JULY 2, 1908.

To the Boards of Water Commissioners of the Towns of Abington and Rockland.

GENTLEMEN: — In accordance with your request of May 29, 1908, for an examination of the conditions about Great Sandy Pond and advice as to the best plan of protecting the purity of the water supply taken therefrom, the State Board of Health has caused the pond and its tributaries to be examined by its engineer.

The results of this examination show that the number of cottages about Great and Little Sandy ponds has nearly doubled in the last five years, and that there has been a great increase in the number of persons who resort to these ponds during the summer season.

In response to an application for advice as to protecting the purity of the water of this source in 1903, the Board stated that on account of the use of the ponds as a summer resort there would be great and

increasing difficulty in preventing the pollution of their waters, unless the control of the lands about them should be acquired by the towns.

It was evident that the cost of acquiring the necessary property, even at that time, would be large, and in view of the circumstances the Board recommended an investigation to determine the practicability of obtaining an adequate supply of water for the towns from wells or other suitable works in the neighborhood of Great Sandy Pond. This advice has not been carried out, and in the mean time the conditions affecting unfavorably the purity of the water of the ponds have grown much worse.

It is impracticable, in the opinion of the Board, to protect adequately the purity of the water of Great Sandy Pond unless much of the property about it and about Little Sandy Pond shall be acquired by the towns and the further use of these ponds as a summer resort prevented. The cost of acquiring the lands, buildings and other property necessary to protect this water supply adequately would now be so great that there is very little doubt, in the opinion of the Board, that it would be much less expensive to discontinue the further use of water taken directly from the pond, and secure water, if practicable, from the ground near the pond by means of wells or other suitable works, as advised by the Board in its communication of April 2, 1903.

While an unsuccessful attempt was made, when the works for taking water from Great Sandy Pond were first built, to obtain water from a filter-gallery near the present pumping station, it does not appear that any further investigation as to the practicability of obtaining a ground-water supply in this region has ever been made, and the Board again recommends that you make a thorough examination of the region about the pond to determine definitely the practicability of obtaining there a ground-water supply suitable for the requirements of the towns. If a ground-water supply can be obtained at no great distance from your present pumping station, the cost of works and of the necessary land for adequately protecting the purity of the supply will not be great. It is important, however, that there be no unnecessary delay in carrying out this work, since the number of buildings about the pond is increasing rapidly and favorable localities for obtaining ground water are likely soon to be occupied.

In carrying out this work it is very important that you secure the assistance of an engineer of experience in the investigation of ground-water supplies, and if you decide to make the investigation advised, the Board will, upon application, give you such assistance as it can by making the necessary analyses of water, and will give you further advice when the results of the investigation are available.

AMESBURY (WELL).

AUG. 6, 1908.

To HERBERT G. LESLIE, M.D., *Secretary Board of Health, Amesbury, Mass.*

DEAR SIR: — In response to your request of July 13 for an examination of the water of a well used to supply 16 families at Lake Attitash, and advice as to its quality, the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The water, when examined, had a very offensive odor, and was found upon analysis to contain a considerable number of bacteria, including those characteristic of sewage. The quantity of organic matter present, also, was higher than is found in good well waters, and there are numerous sources of pollution in the immediate neighborhood of the well. In the opinion of the Board the water is unsafe for drinking, and the Board recommends that its use for that purpose be prevented.

ANDOVER.

Under the provisions of section 113 of chapter 75 of the Revised Laws, rules and regulations were made by the Board on Aug. 6, 1908, for preventing the pollution and securing the sanitary protection of the waters of Haggett's Pond and its tributaries, used by the town of Andover as a source of water supply.

ATHOL.

NOV. 12, 1908.

To the Board of Water Commissioners of the Town of Athol.

GENTLEMEN: — The State Board of Health received from you on Nov. 4, 1908, an application, under the provisions of chapter 25, section 35, of the Revised Laws, requesting approval by this Board of the taking of water from Lake Ellis, so called, as a temporary water supply for the town of Athol, the storage reservoirs by which the town is supplied having been drawn to a very low level.

The Board has caused the proposed source of temporary supply to be examined by one of its engineers and a sample of the water to be analyzed.

An examination of the watershed of the lake shows that it contains many dwelling houses, located both in the immediate neighborhood of the lake and along the streams which feed it, from some of which pollution evidently finds its way into the lake. In the opinion of the Board the conditions are such at the present time that this lake cannot be regarded as a safe source from which to take water for drinking, and

in case it should become essential to introduce water from this lake, all of the water used for drinking should be boiled.

The quantity of water remaining in the reservoirs is still sufficient to last for a considerable period, and under the circumstances the Board recommends that you cause an investigation to be made without delay, with the assistance of an engineer of experience in matters relating to water supply, to determine whether it is not practicable to obtain from some available source a sufficient quantity of water for the supply of the town, which can be used with safety for drinking. It is possible that a sufficient additional supply can be obtained from the ground, either in the valley below the Phillipston reservoir or at some other point in the neighborhood of your present works.

The Board will give you such assistance as it can in making these investigations and will promptly advise you as to any source that you may select.

AVON.

MAY 7, 1908.

To the Board of Water Commissioners of the Town of Avon.

GENTLEMEN: — The State Board of Health received from you on April 8, 1908, an application for advice with reference to a proposed additional water supply for the town of Avon, containing the following outline of your proposed plan: —

On the grounds where our present water supply is located we have drilled a well 200 feet deep, about 400 feet distant in a northeasterly direction from the source of our present water supply. We now propose to drill another well on the same grounds, about half way between the well just completed and our present water supply. We intend to force the water by compressed air from these wells into the well which now furnishes our water supply.

In response to this application the Board has caused the locality to be examined by its engineer and samples of the water from the deep tubular well already completed to be analyzed.

The results of the analyses show that the water is similar in character in most respects to the water of the large well from which your supply is now drawn, but it contains a larger quantity of iron than is found in good ground waters, and though safe for drinking may be objectionable for laundry and other uses.

The quantity of water obtainable from this well is not likely to be a very material addition to the supply of water available for the use of the town, and it is unlikely that a considerable addition will be made to the yield of your present sources of supply by sinking a second well in this region. The experience with wells in such locations, sunk deeply

into rock, has not been a favorable one, so far as obtaining considerable quantities of water therefrom is concerned, and it is very doubtful, in the opinion of the Board, whether these wells, used in connection with your present sources of supply, will furnish a sufficient quantity of water for the requirements of the town.

The Board recommends that before sinking additional wells in the locality about your present works you cause an investigation to be made to determine the practicability of securing a sufficient additional supply of water of good quality from some other locality within a reasonable distance of the village.

The Board would advise that in further investigations you secure the assistance of an engineer of experience in matters relating to water supply, and the Board will assist you by making the necessary analyses of water and will give you further advice when you have the results of further investigations to present.

Bedford.

April 2, 1908.

To the Board of Water Commissioners of the Town of Bedford, Messrs. George M. Dimond, Henry D. Lyons and Charles A. Burke.

Gentlemen: — The State Board of Health received from you on March 21, 1908, an application for the approval of the use of Kenrick Brook, so called, and of ground water in the valley thereof near the ice pond east of Shawsheen Road in Bedford as a source of water supply for the town, accompanied by a report and plans of your engineer describing the proposed works.

The plans provide for constructing a well 25 feet in diameter and 21 feet deep at the location of certain wells from which a pumping test was recently made at a point about 130 feet below the dam of the present ice pond; for enlarging the ice pond to a capacity of 3,000,000 gallons or more, and for the construction of a filter, on land surrounding the proposed well, which will have a bottom area of 9,260 square feet. The bottom of the collecting well in the plans presented is at grade 101, and the bottom of the filter at grade 122. The bottom of the filter surrounding the well is to be about 17 feet distant from the outer wall of the well. It is proposed, when the yield of the well is insufficient to furnish the amount of water required, to supplement it by turning water from the pond upon the filter, which can be flowed to a depth of about 3 feet and would then hold about 240,000 gallons. Your engineer further states that it is probable that in the future an additional supply might be obtained by going farther up the valley and collecting the water of various springs into small wells or basins, and leading the same by direct pipes to the large collecting well.

The Board has caused the locality of the proposed works to be examined by one of its engineers and has considered the plans and report presented and the results of pumping tests made by pumping from a group of 5 wells at various times between January 10 and February 4.

The results obtained from the test wells showed that the soil was quite porous to a depth of a little over 20 feet below the surface of the ground in the neighborhood of the proposed permanent well, and that water could be obtained quite freely therefrom.

The results of the pumping tests indicate that the quantity obtainable from the ground in this locality is somewhat limited and probably not more than sufficient, in the drier part of the year, for the present requirements of the town of Bedford, assuming a reasonable rate of use of water. By enlarging the ice pond so as to hold at least 3,000,000 gallons, and cleaning the bottom by removing the soil and organic matter therefrom, as in the plan now proposed, the yield of the well may be increased somewhat, and, by utilizing the water of the pond to increase the yield of the well by applying it to the ground about it, there is no doubt that a very considerable increase in the yield of that source could be secured, and the quantity obtainable in this way should be sufficient for all the reasonable requirements of the town of Bedford, allowing for a considerable increase in the population of the town.

The quality of the water obtainable from the ground at this place, as shown by the samples collected during the pumping tests referred to above, was found to be good, and the watershed of the pond contains but one dwelling house from which drainage is likely to affect the quality of the water. You state that you propose to acquire this dwelling house and the buildings used in connection therewith to protect the quality of the water.

The Board approves the proposed source of water supply for the town of Bedford, under the provisions of chapter 131 of the Acts of the year 1907.

With regard to the construction of the proposed filter about the large well, as shown on the plan submitted, the Board would advise that the filtered water be kept as far from the well as practicable so that it may have to filter through as great a depth of soil as possible before entering the well. It is also desirable that provision be made so that the filter cannot be filled to a depth greater than about 1 foot. It is very important that the plan of operating this filter intermittently be adhered to, and it is likely that better results will be secured by applying water more frequently and in smaller quantities than would be the case if the filter were filled to a depth of 3 feet, as suggested.

It is very important that the consumption of water be kept within

reasonable limits, and to this end the works should be constructed with care, to avoid leakage, and all water drawn from the mains, except from hydrants used for fire purposes, should be metered.

AUG. 18, 1908.

To the Board of Water Commissioners of the Town of Bedford, MR. GEORGE M. DIMOND, *Chairman.*

GENTLEMEN: — The State Board of Health received from you on July 17, 1908, a petition for the consent and approval of this Board of the taking, by purchase or otherwise, of certain lands within the watershed of Kenrick Brook, so called, in the town of Bedford, for protecting and preserving the purity of the sources of water supply of said town, accompanied by a plan and description of the said lands.

In response to this petition the Board gave a hearing at its office, Room 141, State House, on Thursday, Aug. 6, 1908, after publishing notice of said hearing in the "Lowell Courier-Citizen," the "Boston Herald" and the "Boston Daily Globe."

After the hearing and an examination of the lands proposed to be taken, as described in your petition, the Board voted to consent to and approve the taking by the board of water commissioners of the town of Bedford of certain lands now or formerly of Lucy L. Kenrick and others, held by Abram E. Brown, trustee under the will of Anthony Holbrook, containing 42.56 acres more or less; and to approve the taking of a parcel of land, with the buildings thereon, now or formerly of Frederick Mahoney of Bedford, containing 4.47 acres more or less, said lands being shown on a plan entitled, "Bedford Water Supply, Bedford, Mass. Plan showing Lands to be taken for Protection of Source of Supply. Scale 100 Ft. Per In. July 14–1908. E. Worthington Eng'r.;" but the Board voted not to consent to or approve the taking of lands of Charles W. Jenks, described in the petition and shown on said plan, it appearing that these lands as at present used are not a menace to the purity of the Bedford water supply, and the owner thereof having stated at the hearing that he would agree not to use the lands in such a way as might be regarded by the State Board of Health as endangering the purity of the water supply.

The lands, the taking of which is herein approved, are bounded, measured and described as follows: —

1. Land held by Abram E. Brown, trustee under the will of Anthony Holbrook for Mrs. Lucy L. Kenrick and others: —

Beginning at land owned by George Kenrick on the Shawsheen Road in said Bedford at the southeasterly corner of said Kenrick land where the same joins the property held by Abram E. Brown, Trustee, and land now

held by the Town of Bedford for Water Supply purposes, thence running in a course South 1° 52′ West 353 feet, thence South 24° 58′ East 192.5 feet, thence South 52° 53′ East 222.7 feet, thence South 60° 16′ East 331.3 feet, thence South 58° 38′ East 126 feet, thence North 41° 08′ East 67 feet, thence North 49° 1′ West 115 feet, thence North 14° 16′ West 139 feet, thence North 37° 59′ West 150 feet, thence North 27° 10′ East 134 feet, thence North 56° 58′ West 149.4 feet, thence South 62° 20′ West 155 feet, thence North 88° 08′ West 68 feet, thence North 1° 52′ East 321 feet, all of said courses and distances bordering on land now held by the Town of Bedford for Water Supply purposes, thence South 74° 15′ East 200.44 feet, thence South 66° 25′ East 672.75 feet, thence South 46° 02′ East 613.6 feet, thence South 56° 08′ East 630.95 feet, thence South 23° 06′ East 449 feet, said courses and distances last named bordering on other properties held by said Abram E. Brown, Trustee, and extending with the last named course to land belonging to William G. Craig and the Town line between Bedford and Lexington, thence running South 71° 59′ West by land of said Craig and Frederick Mahoney and along said Bedford and Lexington town line 933.5 feet to other land of Frederick Mahoney, thence running North 24° 11′ West 383 feet, thence South 68° 12′ West 175.8 feet, thence South 83° 48′ West 277 feet, on land of said Frederick Mahoney to land owned by Charles W. Jenks et al., thence running North 11° 15′ West 449.7 feet to a stone bound, thence North 73° 45′ West 676.7 feet to a stone bound, the last two courses and distances being along the property of Charles W. Jenks et al. and extending to other property held by said Abram E. Brown, Trustee, thence running North 13° 42′ West 651.4 feet, thence North 34° 27′ East 137.65 feet, thence North 23° 58′ East 125 feet, thence North 14° 14′ East 114.4 feet along land held by said Abram E. Brown, Trustee, to the land owned by George Kenrick first mentioned in this description, thence running South 74° 15′ East 40.7 feet along land of said George Kenrick to the point of beginning, containing 42.56 acres.

2. Land held by Frederick Mahoney: —

Beginning at the easterly corner of said lot at land of Abram E. Brown, Trustee, thence running by a magnetic course South 71° 59′ West 528.35 feet along other land of said Mahoney and on the town line between Bedford and Lexington to land of Charles W. Jenks, thence running North 11° 15′ West 440.9 feet on said Jenks' land to land of Abram E. Brown, Trustee, thence running North 83° 48′ East 277.0 feet, thence North 68° 12′ East 175.8 feet, thence South 24° 11′ East 383.0 feet, all of said last three courses and distances on land of Abram E. Brown, Trustee, and extending to the point of beginning of said description, containing 4 47/100 acres.

BELCHERTOWN.

MARCH 5, 1908.

To Messrs. NELSON RANDALL, D. D. HAZEN and C. E. WITT, *Board of Selectmen of the Town of Belchertown.*

GENTLEMEN: — The State Board of Health received from you on Jan. 28, 1908, an application for advice with reference to a proposed water supply for Belchertown, to be taken from Pratt Brook, a tributary of Jabish Brook, in the westerly part of the town, and has caused the proposed source of supply to be examined by one of its engineers and a sample of the water to be analyzed.

The results of the analysis show that the water flowing in Pratt Brook at the time this examination was made was of good quality for water-supply purposes.

The area of the watershed of Pratt Brook above the lowest point from which it is practicable to supply the village by gravity is so small that a storage reservoir of considerable size would be necessary to insure an adequate supply of water at all times, and it is impracticable, on account of the depth of snow, to determine at the present time whether the conditions in the valley of this brook are favorable for the construction of a reservoir of the necessary size and at such an elevation as will furnish an adequate and efficient supply for the village by gravity. Moreover, it appears from an examination of the State map and other information available to the Board that there may be other sources from which a supply of water for Belchertown may be obtained more advantageously than from Pratt Brook.

The Board will, if you so request, make a further examination of the proposed source of supply and other available sources after the snow disappears and the conditions become favorable for such an examination, and will give you further advice as to your proposed plans if you will present them.

BOSTON (CLIFTON MANUFACTURING COMPANY).

JULY 2, 1908.

To the Clifton Manufacturing Company, Boston, Mass.

GENTLEMEN: — In response to your request of June 23, 1908, for an examination of the water of a new deep tubular well recently put in at your factory on Brookside Avenue, Jamaica Plain, and advice as to its use for drinking, the Board has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water is very hard and to this extent objectionable for drinking. It was also found to contain a larger number of bacteria than are found in good well waters, and in

its present state the water of this well cannot be considered safe for drinking.

It is possible that the present condition of the water is due in part to pollution introduced in sinking the well, and it may be derived from some of the many possible sources of pollution in the neighborhood of the factory. A further examination after the well has been in use for a time and a large quantity of water has been drawn therefrom might show a material change in its quality.

BRAINTREE (WELL OF A. H. SANFORD).

MAY 7, 1908.

To the Board of Health of the Town of Braintree.

GENTLEMEN: — In response to your request of April 16, 1908, for an examination of the water of a well at the house of A. H. Sanford in South Braintree, and advice as to its quality, the Board has caused the well and its surroundings to be examined by one of its engineers and a sample of the water to be analyzed.

The results of the analysis show that the water of this well has been badly polluted and contains more organic matter than is found in a good well water. It appears that water from the public water supply is available for use in this house, and the Board would recommend that the further use of the well be discontinued.

BROCKTON.

APRIL 2, 1908.

To the Board of Water Commissioners of the City of Brockton.

GENTLEMEN: — The State Board of Health received from you on March 3, 1908, an application requesting the approval by this Board of the taking of certain parcels of land at Silver Lake for the purpose of preserving the quality of the water supply of the city of Brockton, shown upon a plan submitted with your application.

The Board has caused the lands in question to be examined by one of its engineers and is of the opinion that it is important for the city to control these lands in order to protect the purity of its water supply.

The Board, acting under the provisions of chapter 356 of the Acts of the year 1899, hereby approves the taking of the lands shown upon the plan entitled "Plan showing land of Brockton Water Works, and Adjoining Parcels in Pembroke and Halifax Mass. Jan. 1908. Scale, 600 ft. = 1 in." Shaded areas on this plan show "Land which the city of Brockton desires to seize for the protection of the purity of its water supply."

The lands, the taking of which is hereby approved, are bounded, measured and described as follows: —

A certain parcel of land situated in Pembroke, Mass., owned by one Studley and William P. Nason, containing 1 acre, bounded and described as follows, — North by land of the city of Brockton, East by Silver Lake, South by land of the city of Brockton, and West by land of John P. Blakeman.

Another parcel of land containing 1½ acres more or less, owned by John P. Blakeman, and bounded and described as follows, — North by land of the city of Brockton, East by land of one Studley, South by land of the city of Brockton, and West by land taken by the city of Brockton for a pipe line, in 1903.

Another parcel of land, containing 4,800 square feet, more or less, said to be owned by W. T. Donovan of Boston, Mass., designated as lots Nos. 986 and 987 on a plan of house lots owned by the Silver Lake Land Co., in Pembroke, Mass., and Halifax, Mass., drawn by J. C. Torrey, C. E., in April, 1889, and on file at the Plymouth County Registry of Deeds.

Another parcel of land containing 4800 square feet, more or less, said to be owned by T. W. Beach, designated as lots No. 1128 and No. 1129 on the above mentioned plan.

Another parcel of land, containing 81,000 square feet, more or less, owners unknown, designated as lots No. 901 to No. 910 inclusive, and No. 972 to No. 981 inclusive, on C St., and lots No. 1041 to No. 1050 inclusive on D St., with that portion of C St. between lots No. 900 and No. 921, all as shown on the above mentioned plan.

Also all that parcel of land owned by parties unknown, situated at the corner of Pembroke Road and D St., comprising lots Nos. 1018 and 1019 as shown on said plan.

Also all that parcel of land owned by parties unknown, situated between D and E Sts., Pembroke Road and G street, with the land included in said streets, all as shown on the above mentioned plan, with the exception of lots Nos. 1091, 1092, 1093, 1105, 1106, 1170, 1171, 1123, and 1124, which are now owned by the city of Brockton.

Also all that parcel of land owned by parties unknown, situated south of E street, between Pembroke Road and Silver Lake, as shown on the above mentioned plan.

The general location of all these tracts is shown on a plan dated January, 1908, drawn by Charles R. Felton, City Engineer of Brockton, and accompanying this description.

Brookfield (East Brookfield).

June 29, 1908.

To the Board of Health of the Town of Brookfield.

Gentlemen: — In response to a request from a member of your board for information as to the true condition of the domestic water supply obtained from wells in the village of East Brookfield, the Board has caused 12 wells in various parts of the village to be examined and samples of their waters to be analyzed. The wells selected for exam-

ination are those used by the greatest numbers of persons, and in all cases the wells examined are used for domestic purposes by from 12 to 40 persons, except the well at the mill of Mann & Stevens, which is probably used by a much larger number.

The results of the analyses of the water of 10 of the wells show that it has been very badly polluted by sewage and not thoroughly purified in its passage through the ground before entering the wells. The numbers of bacteria present in the waters of most of these wells were high, and in many of them bacteria characteristic of sewage were found to be present. In the opinion of the Board the further use of the waters of any of these wells for domestic purposes is likely to cause sickness.

The waters of 2 of the wells, — those located respectively at the houses of W. J. Vizard and H. L. Gleason, — though badly polluted were evidently, at the time of this examination, being quite well purified in their passage through the ground before entering the wells, and in the condition in which they were found at this time the waters of these wells may not be unsafe for drinking; but changes in the circumstances affecting their pollution may at any time render these waters unsafe, and the Board cannot recommend their continued use.

The results of the examination show that there is very great need of a general water supply in this village, and the Board would recommend that a supply of good water from some suitable source be introduced as soon as possible.

Chelmsford (North Chelmsford Fire District).

Nov. 5, 1908.

To the Board of Water Commissioners of the North Chelmsford Fire District,
Mr. C. Frank Butterfield, *Chairman.*

Gentlemen: — The State Board of Health received from you on Oct. 8, 1908, an application for advice as to the quality of the water of 10 new test wells located south of your pumping station near Crystal Lake, and forming a continuation of the lines of wells already in use there, and in response the Board has caused the locality to be examined by one of its engineers and samples of the water from the wells to be analyzed.

The results of the analyses indicate that the water is very soft and in other respects of good quality, and quite similar in character to that of the wells now in use. In the opinion of the Board these wells are an appropriate enlargement of your sources of supply, and will make it practicable to obtain from the ground with greater facility the quantity of water required for the supply of the village.

CHICOPEE (FAIRVIEW).

SEPT. 3, 1908.

To the Fairview Municipal Club, J. H. ROSS, *President*.

GENTLEMEN: — In response to your petition of July 17, 1908, the Board has caused an examination to be made of the wells in the village of Fairview and samples of water from a number of the wells to be analyzed.

The results indicate that the wells used for domestic water supply are generally badly polluted, and in view of the conditions found the Board has advised the city of Chicopee of the necessity of providing a public water supply in this village.

A copy of the communication of the Board to the city of Chicopee is enclosed herewith.

SEPT. 3, 1908.

To Hon. J. O. BEAUCHAMP, *Mayor of the City of Chicopee*.

DEAR SIR: — In response to a request from the village of Fairview, in the city of Chicopee, for an examination of the drinking water in wells in that village, which is not provided with a public water supply, the Board has caused 12 wells in various parts of the village to be examined and samples of their waters to be analyzed.

The results of the analyses show that the waters of most of the wells have been at some time very badly polluted by sewage and not thoroughly purified in their subsequent passage through the ground before entering the wells. The numbers of bacteria present in the waters of the wells were in most cases high, and in many of them bacteria characteristic of sewage were found to be present. In the opinion of the Board the further use of water from any of these wells for domestic purposes may cause sickness.

The wells selected for examination were quite evenly distributed through that portion of the village of Fairview situated upon the higher lands in Chicopee, near the boundary line between Chicopee and South Hadley, and the condition of the wells examined is doubtless a fair indication of the general condition of the numerous wells in this section. The level of the ground water is not far beneath the surface, and water appears to be obtained readily from comparatively shallow wells, and as practically all of the sewage and foul drainage from the dwellings is discharged into vaults and cesspools which are located at no great distance from the wells, the pollution of these sources of water supply is inevitable and will be likely to increase.

In the opinion of the Board it is essential, for the proper protection of the public health in this village, that a public water supply be introduced as soon as practicable and the further use of water from wells

in this thickly settled area discontinued; and the Board recommends that the city of Chicopee take the necessary steps to provide a general supply of good water for the use of the inhabitants of Fairview.

COHASSET.

MAY 7, 1908.

To the Cohasset Water Company, Cohasset, Mass.

GENTLEMEN: — The State Board of Health received from you on May 5, 1908, through your engineer, — Mr. William S. Johnson of Boston, — the following application for advice with reference to a proposed water supply for Cohasset: —

The Cohasset Water Company applied to you on July 5, 1907, for advice with reference to an additional water supply, to be taken from the ground on the westerly side of Bound Brook, a short distance north of Doane Street. It was proposed to supplement the supply, when necessary, by pumping upon the ground in the vicinity of the well water taken either from the ground in the adjacent swamp or from the brook, or even from Lily Pond, water from which can be brought to this place through an open ditch. You advised that before beginning the final construction of works one or two wells be sunk at this location, and that water be pumped from them for a period of several days in order to determine definitely whether enough water is likely to be obtained here for the requirements of the town.

In accordance with this advice 2 test wells have been sunk, the location of which is shown on the accompanying plan. The first well was sunk during the fall of 1907, and water was pumped from it for a period of seven days at a rate of about 300,000 gallons per day. Samples of the water were sent to you each day during the test for examination. The soil through which this well was sunk was in part very coarse gravel, through which for a period of several days in order to determine definitely whether enough was imperfectly purified.

The second well, which has been recently sunk, passed through white sand of uniform size. Water was pumped from this well continuously for a period of seven days at a rate of about 260,000 gallons per day, with a slight lowering of the ground water in the vicinity. The indications furnished by the tests are that a large quantity of water can be obtained from the ground at this place.

The Cohasset Water Company wishes to obtain your advice with reference to the plan proposed on July 5, 1907, in the light of the further tests which have been made.

The plan presented last year provided for sinking a well in an area of sandy land on the westerly side of Bound Brook, a short distance north of Doane Street, and for supplementing the yield of the well when necessary, especially during the summer season, by pumping water from the

brook or other source upon the ground about the proposed well. In carrying out this plan the proposed filters were to be located about 100 feet from the well, and were to be of such an area that an ample supply of water would be obtained for the town when filtering at a rate not greater than 500,000 gallons per acre per day.

The test made last fall by pumping from a well near the northerly end of the area referred to indicated that the ground water in that locality was affected by iron to such an extent that it would be of poor quality for water-supply purposes. Recently a second well has been sunk near the middle of the sandy area, and during a pumping test made by pumping continuously from the new well for a period of seven days the yield of the well averaged about 260,000 gallons per acre per day, indicating that water can be obtained very freely from the ground at this place.

The results of analyses of samples of water collected daily during the recent test show that the water is of good quality for domestic purposes. The high chlorine and nitrates present in this water were doubtless due to fertilizer used upon the ground about the well previous to the test, the effect of which would doubtless disappear if water should be drawn continuously from the ground at this place.

The results of the test as a whole indicated that by constructing a well of as great a depth as practicable at the location in which the recent test was made, and supplementing its yield by applying water to filters about the well at a distance of at least 50 feet therefrom, as proposed in the plan submitted last year, water of good quality can be obtained from this locality and in sufficient quantity for all the requirements of the town. As stated in the reply of last year, it is possible that better results would be obtained by taking water for filtration from the ground in the swamp 500 feet or more north of the wells than by taking water directly from the brook. The ground water from the region indicated, however, is affected by an excess of iron, and if it is used it is important that it be thoroughly aerated before it is applied to the filters.

The plan in general appears to be a practicable method of securing an additional supply of good water for the town of Cohasset.

Dudley (Well of J. Prescott).

July 2, 1908.

To Mr. J. Prescott, *Webster, Mass.*

Dear Sir: — In response to your request of June 26, 1908, for an examination of the water of a well at your factory in Dudley, and advice as to its use for drinking, the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water entering the well has been at some time seriously polluted, but subsequently well purified in its passage through the ground before entering the well, and in the condition in which it was found at the time this examination was made the water was probably safe for drinking.

It appears, however, that the well is located only a few feet from the French River, which is badly polluted in the vicinity of the well, and there is some evidence that surface water finds its way directly into the well at times of rain. It is probable, under these conditions, that the water entering the well is at times not wholly purified, and in the opinion of the Board the well cannot be regarded as a safe source from which to take water for drinking.

EASTHAMPTON.

OCT. 8, 1908.

To the Water Supply Committee of the Town of Easthampton, Mr. F. W. PITCHER, *Chairman.*

GENTLEMEN: — In response to your request of Sept. 30, 1908, for advice as to the use of water from tubular wells in the valley of Broad Brook for the supply of the town of Easthampton, the Board has caused the wells and their surroundings to be examined by its engineer and samples of their waters to be analyzed.

The results of the analyses show that the water is clear, colorless and odorless, and while somewhat harder than that of Bassett Brook, your present source of supply, is of excellent quality for water-supply purposes. The test wells penetrated a porous stratum, from which water flows very freely, and the aggregate quantity flowing naturally from the wells is greater than is necessary for the supply of Easthampton. A greater quantity of water than flows from the wells can doubtless be made available by pumping. On account of the nearness of the wells to the town the cost of works for supplying water will not be large.

The results of the test are very satisfactory and indicate that an ample supply of good water sufficient for the requirements of the town of Easthampton can be obtained from the ground in the valley of Broad Brook, and in the opinion of the Board this source is the most appropriate of those available for the supply of the town.

If works shall be constructed to take water from the ground in the valley of Broad Brook it is very important that they be designed and their construction supervised by an engineer of experience in matters relating to ground-water supplies. It will also be necessary to provide a covered distributing reservoir to replace the open reservoir now in use, since in order to avoid deterioration ground water must be kept

from exposure to light. It is important, also, for the town to control a considerable area of land about the wells in order to prevent danger of their pollution.

EASTON (NORTH EASTON VILLAGE DISTRICT).

OCT. 1, 1908.

To Mr. EVERETT E. POOL, *Treasurer North Easton Water Works, North Easton, Mass.*

DEAR SIR: — In response to your request of Sept. 16, 1908, for an examination of the water of a deep tubular well located about 60 feet east of your main well, from which you propose to take water for the supply of the North Easton Village District, the Board has caused the locality to be examined by its engineer and samples of the water of the well to be analyzed.

A previous examination of this well about four years ago showed that the quality of the water was not satisfactory, and a comparison of the results of the analyses of samples collected recently with those examined at that time does not show that any material improvement has taken place, and the Board does not advise the use of the well in question as a source of water supply for the district.

At the time of the examination of the well in 1904 the Board examined the sources of supply then in use and called attention to the objections to the use of water from pipes beneath the storage reservoir above the well at the pumping station, and the Board recommended that the district cause an investigation to be made with a view to obtaining an additional supply of water sufficient for its requirements from some suitable source, but it does not appear that any action has yet been taken upon that recommendation.

It is very important, in the opinion of the Board, that an adequate supply of water which is safe for drinking should be made available as soon as practicable, and the Board again recommends that you take up this question without further delay. In making the necessary investigations it is important that you secure the assistance of an engineer of experience in matters relating to ground-water supplies. A copy of the advice of the Board of 1904 is enclosed herewith.

EVERETT (WELL).

JUNE 4, 1908.

To Mr. J. E. FREEMAN, *122 Cottage Street, Everett, Mass.*

DEAR SIR: — In response to your request for an examination of the water of a well situated near the corner of Broadway and Chelsea Street in Everett, from which it is proposed to take water to supply for drink-

ing in certain stores, tenements, etc., the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water is very badly polluted and unfit for drinking, and the Board recommends that its use for drinking be prevented.

Fitchburg.

Jan. 14, 1908.

To the Board of Water Commissioners of the City of Fitchburg.

Gentlemen: — The State Board of Health received from you on Oct. 28, 1907, a communication stating that it is your practice, in laying service pipes in the city of Fitchburg, to use a pipe of wrought iron lined with cement, connecting it with the main by a section of lead pipe about 14 inches in length, and requesting information upon the following questions: —

> Is there danger from the lead used to make the joints in the mains?
> Would it be better to use a tin-lined connection at the main?
> What can be done to reduce any possible danger from lead in the water?

It further appears that the mains used in the city of Fitchburg are for the most part cast iron with lead joints, and that the city service pipes terminate inside the cellar walls of the buildings, from which point lead pipes are commonly used by the owner in distributing the water through the buildings.

The Board, in response to your request, has caused a number of samples of water from hydrants and service pipes in different parts of the city to be collected by one of its engineers and analyzed, and has considered the available information relative to the questions submitted.

The results of analyses of samples of water collected from hydrants in different parts of the city since your application was received show that out of six hydrant waters examined lead was present in only one case, and in that case the quantity found was very small. A sample of water collected from a faucet in the cellar of a building in Summer Street, at the junction of the city's cement-lined service pipe with the lead pipe through which water is distributed to the building, also contained a very small quantity of lead; and a sample from a faucet in the kitchen of this house, after the water had passed through about 40 feet of lead pipe, was found to contain a slightly greater quantity. A sample from a faucet in a house on Pine Street, where the water had passed through both a cement-lined service pipe and about 60 feet of lead pipe inside the premises, showed the presence of a little over twice the quantity of lead found in the water of the sample from Summer Street,

which had passed through 40 feet of lead pipe, but the quantity of lead found in this sample after passing through 60 feet of lead pipe was only .0206 of a part per 100,000, a quantity much less than the minimum amount known to have caused lead poisoning. The greatest quantity of lead present in any sample collected in Fitchburg and analyzed for lead was found in a sample sent to the laboratory of the Board by your department on April 23, 1907, the certificate indicating that it was collected from a faucet on Prichard Street. In this case the quantity of lead present, which amounted to .0286 of a part per 100,000, was but little over half the minimum amount known to have caused lead poisoning. Other samples from this faucet contained considerably smaller quantities of lead.

The results of the investigations thus far made indicate that the quantity of lead taken up by the Fitchburg water in passing through the mains and cement-lined service pipes is insignificant, nor is there any evidence from these examinations that the city water in passing through lead pipes whose length does not exceed 80 feet, used to distribute the water in buildings, takes up a sufficient quantity of lead to cause injury to health.

It is possible that the action of the water upon lead pipe varies from time to time, and its action may possibly be somewhat greater in some seasons than in others. Under the circumstances, any possible danger from the action of the water upon lead pipe would be practically removed by continuing the cement-lined service pipe inside the buildings, at least to the points at which water is drawn for drinking. Tin-lined lead pipes, if properly made, or tin-lined iron pipes may also be used with safety.

The quantity of lead taken up by the water in passing through the short lead connection at the main is unlikely to be large enough under the existing circumstances to be injurious to health.

JULY 2, 1908.

To the Board of Water Commissioners of the City of Fitchburg.

GENTLEMEN: — The State Board of Health received from you on May 18, 1908, a petition for the consent and approval of this Board of the taking, by purchase or otherwise, of certain lands within the watershed of Meetinghouse Pond, in the town of Westminster, for the purpose of preserving and improving the purity of the water of said pond, which is used as a source of water supply by the city of Fitchburg, accompanied by a plan and description of said lands.

In response to this petition the Board gave a hearing at its office, Room 141, State House, on Thursday, June 4, 1908, after publishing notice of said hearing in the "Fitchburg Daily News," the "Fitchburg Sentinel" and the "Gardner News."

After the hearing and an examination of the lands proposed to be taken, as described in your petition, the Board after consideration voted to consent to and approve the taking by the city of Fitchburg of so much of the lands, with buildings thereon, now or formerly of S. Dwight Simonds, located between land now owned by the city of Fitchburg on the westerly shore of Meetinghouse Pond and the Westminster road, amounting to about 30.66 acres, as are shown on the plan presented with your petition, entitled "Plan of proposed taking of land on the watershed of Meetinghouse Pond in Westminster, Mass. by the City of Fitchburg, to accompany order No. 451, May 5, 1908."

The lands, the taking of which is herein approved, are bounded, measured and described as follows: —

A certain tract of land situated in the southerly part of the town of Westminster and described as follows: — Beginning at the most northerly corner thereof on the road from Westminster to Hubbardston at the corner of land of Levi Baker thence southeasterly on land of said Baker about 654 feet to a point in the line of the five rod taking around Meetinghouse Pond, thence southerly on the line of said taking 34.3 feet to stone bound marked 33, thence southerly 301.39 feet to stone bound marked 32, thence southwesterly 160.09 feet to stone bound marked 31, thence southerly 194.64 feet to stone bound marked 30, thence southwesterly 67.48 feet to stone bound marked 29, thence southwesterly 253.58 feet to stone bound marked 28, thence southerly 147.98 feet crossing a brook to a stone bound marked 27, thence southeasterly 67.4 feet, thence southwesterly on land of S. Dwight Simonds 346.5 feet, thence northwesterly on land of said Simonds 576 feet, thence southwesterly on land of said Simonds 478 feet to the road first mentioned, thence northwesterly on said road 404.3 feet to land of Artemas Baker, thence southeasterly 178.53 feet on land of said Baker, thence northeasterly 223.62 feet on land of said Baker, thence westerly 180.2 feet on land of said Baker to said road, thence northeasterly on said road 229 feet to an angle, thence northeasterly on said road 118.5 feet to an angle, thence northeasterly on said road 132.2 feet to an angle, thence northeasterly on said road 447.7 feet to an angle, thence northeasterly on said road 331.7 feet to the place of beginning, containing about 30.66 acres of land, and including all buildings located thereon, comprising a tract of land taken by the City of Fitchburg of S. Dwight Simonds.

JULY 2, 1908.

To the Board of Water Commissioners of the City of Fitchburg.

GENTLEMEN: — The State Board of Health received from you on May 18, 1908, a petition for the consent and approval of this Board of the taking, by purchase or otherwise, of certain lands within the watershed of Wachusett Lake, in the towns of Westminster and Princeton, for the purpose of preserving and improving the purity of the water

of said lake, which is used as a source of water supply by the city of Fitchburg, accompanied by a plan and description of said lands.

In response to this petition the Board gave a hearing at its office, Room 141, State House, on Thursday, June 4, 1908, after publishing notice of said hearing in the "Fitchburg Daily News," the "Fitchburg Sentinel" and the "Gardner News."

After the hearing and an examination of the lands proposed to be taken, as described in your petition, the Board after consideration voted to consent to and approve the taking by the city of Fitchburg of certain lands, with buildings thereon, now or formerly of Ann M. Wight, R. R. Cookman and Edna M. Cookman, lying south and southwest of the road from Leominster to East Princeton and between said road and lands now owned by the city of Fitchburg, as shown on the plan entitled "Plan of proposed taking of land on the water-shed of Wachusett Lake in Princeton, Mass. by the City of Fitchburg, to accompany order No. 453, May 5, 1908," being lots numbered 2, 3, 4 and 5 on said plan and containing respectively .55, 36.14, .5 and 9.12 acres or thereabout; and to consent to and approve also the taking by the city of Fitchburg of a certain area of land now or formerly of Edna M. Cookman, northeast of said highway, being lot numbered 1 on said plan and containing about .94 of an acre; but voted not to consent to or approve the taking of lots numbered 6 and 7 on said plan, now or formerly of R. R. Cookman and Edna M. Cookman, respectively, lying northeast of said Princeton road.

The lands, the taking of which is herein approved, are bounded, measured and described as follows: —

1. A certain tract of land situated in the northerly part of Princeton and bounded and described as follows: — Beginning at the northwesterly corner on the road from Westminster to East Princeton and at land of Alphonso Kelley, thence easterly on land of said Kelley about 252.7 feet, thence by an irregular line in a generally southeasterly direction about 307.5 feet on land of said Kelley, thence southwesterly about 64.6 feet to the road above mentioned, thence northwesterly on said road about 283.35 feet to place of beginning, containing about 94/100 acres and including all buildings thereon, it being a tract of land taken by the City of Fitchburg of Edna M. Cookman.

2. A certain tract of land situated in the northerly part of the town of Princeton and bounded and described as follows: — Beginning on the road from Westminster to East Princeton at the corner of land of William M. Powell, thence southwesterly on land of said Powell about 310 feet to land of the five rod strip taken by the City of Fitchburg May 1, 1906, thence southeasterly on line of said taking about 74.2 feet to land of Edna M. Cookman, thence northeasterly on land of said Cookman about 319.7 feet to road above mentioned, thence northwesterly on said road about 80 feet

to place of beginning, containing about 55/100 of an acre of land, including all buildings located thereon, it being a tract of land taken of Ann M. Wight by the City of Fitchburg.

3. A certain tract of land situated in the northerly part of the town of Princeton and bounded and described as follows: — Beginning at the most northerly corner thereof on the road from Westminster to East Princeton and at the corner of land of Ann M. Wight, thence southeasterly on said road about 324.55 feet to land of Robert R. Cookman, thence on land of said Cookman and in a generally southerly direction about 282.75 feet, thence northeasterly on land of said Cookman about 178 feet to the road above mentioned, thence southeasterly on said road about 137 feet to land of John Hoar, known as Redemption Rock land, thence southwesterly on land of said Hoar 140 feet, thence southeasterly on land of said Hoar 98 feet, thence northeasterly on land of said Hoar 140 feet to road above mentioned, thence southeasterly on said road about 729 feet to land of Eli Merriam, thence westerly on said land of Merriam about 167.1 feet to stone bound, thence southwesterly on land of said Merriam 156.74 feet to stone bound, thence southwesterly on land of said Merriam 38.4 feet to stone bound, thence southeasterly on land of said Merriam 479.8 feet to land of one Osgood, thence westerly on land of said Osgood 352 feet, thence northwesterly on land of said Osgood 320.2 feet, thence westerly on land of said Osgood 107.45 feet, thence southwesterly on land of said Osgood 299.5 feet, thence southwesterly on land of said Osgood 374.8 feet to land of the City of Fitchburg formerly owned by Flora H. Plimton, thence northerly on land of said City of Fitchburg 891.7 feet, thence northeasterly on land of City of Fitchburg 865.35 feet, thence northerly on land of said City of Fitchburg 26.1 feet, thence westerly on land of said City of Fitchburg 209.25 feet, thence northwesterly on land of said City of Fitchburg 402.1 feet to line of the five rod taking of land on the shore of Wachusett Lake, thence on the line of said taking northeasterly 71.78 feet, northerly 64.52 feet, and northwesterly 79.35 feet to land of Ann M. Wight, thence northeasterly on land of said Wight about 319.7 feet to place of beginning, containing 36.14 acres and including all buildings located thereon, comprising a tract of land taken by the City of Fitchburg of Edna M. Cookman.

4. A certain tract of land situated in the northerly part of the town of Princeton and bounded and described as follows: — Beginning at the most northerly corner thereto on the road from Westminster to East Princeton and at land of Edna M. Cookman, thence on land of said Cookman in a generally southerly direction about 282.75 feet, thence northeasterly on land of said Cookman about 178 feet to the road above mentioned, thence northwesterly on said road about 226.8 feet to place of beginning, containing about 5/10 of an acre of land and including all buildings located thereon, comprising a tract of land taken by the City of Fitchburg of Robert R. Cookman.

5. A certain tract of land situated in the northerly part of the town of Princeton bounded and described as follows: — Beginning at the most north-

erly corner thereof at the junction of the road from Westminster to East Princeton and the road from Westminster to Leominster, thence southeasterly on said Leominster road 937 feet to a town road, thence southwesterly on said town road 737 feet to the road from Westminster to East Princeton, thence northwesterly on said road about 1200 feet to the place of beginning, containing about 9.12 acres of land, comprising a tract of land taken by the City of Fitchburg of Edna M. Cookman.

FRAMINGHAM.

FEB. 24, 1908.

To the Board of Water Commissioners of the Town of Framingham, Mr. H. L. DAVENPORT, *Secretary.*

GENTLEMEN: — The State Board of Health received from you on Feb. 15, 1908, a communication stating that preliminary investigations have been made with a view to obtaining a new and sufficient water supply for the town of Framingham, and requesting advice relative to the following questions: —

First. — In your opinion is it wise to make this test at this season of the year, or should the same be deferred until the drier portion of the year?

Second. — Our average daily consumption of water for 1907 being 614,000 gallons, do you deem a source of supply of 2,000,000 gallons daily to be sufficient for the town to provide for at a new source of supply, the present source to be abandoned?

Third. — Do the preliminary tests thus far made warrant the town going to the expense of making the fifteen days' continuous pumping test at the wells located on the land of Mr. Robert F. Perkins at Framingham Center, or should further test wells be driven in locations other than those investigated by Mr. VanValkenburgh before the pumping test be undertaken?

Fourth. — If the continuous pumping test at the Perkins location is conducted at this season of the year, and demonstrates that 2,000,000 gallons daily can be obtained there now, would this amount be materially reduced during the drier portion of the year?

Fifth. — Provided a fifteen days' continuous pumping test, conducted at the present season of the year at the Perkins location, developed 2,000,000 gallons daily, would your Board approve such a source of supply, basing your opinion on the data now in your possession?

The application is accompanied by plans showing the location of the test wells in the valley of Baiting Brook, so called, the character of the soil penetrated by the test wells and the amount of water obtainable from each with a hand pump; also by a plan showing the proposed location of a group of 50 tubular wells from which it is now proposed to make a further test.

The Board has caused the locality to be examined by its engineer and has examined the plans and information submitted by you and the results of analyses of water from the test wells collected and sent to the laboratory of the Board by your engineer.

The results of the analyses indicate that water of good quality can probably be obtained from the ground in the locality in which it is proposed to make the pumping test.

An examination of the samples of material collected from the test wells indicates that beneath the surface soil in this valley there is a deep layer of sand, beneath which is a stratum of coarse gravel having a general depth of 10 to 12 feet, from which water could be pumped very freely; and, so far as can be judged from these tests and an examination of the locality, the conditions are favorable for obtaining a large quantity of water from the ground at this place.

In the opinion of the Board, the conditions, as shown by the tests thus far made, are sufficiently favorable to warrant a further and more thorough test of the probable quantity and quality of water obtainable from the ground in the locality indicated. While the present season of the year is not the most favorable one in which to make a test of this kind, it is, nevertheless, practicable, in the opinion of the Board, to determine quite definitely the yield of the proposed source if the test is carried on with care, the quantity of water pumped accurately recorded and careful observations made of the height of the ground water in various wells in the region before, during and after the test. It may be desirable, however, to continue the test for a somewhat longer period than fifteen days, as now proposed, but this question can only be determined after the test is in progress.

In regard to the question as to whether a supply of 2,000,000 gallons daily is a sufficient one for the town to provide in the selection of a new source (the present consumption of water in Framingham being 614,000 gallons per day), it appears to the Board that a quantity of water considerably less than 2,000,000 gallons per day should be ample for all the requirements of the town for many years in the future if the quantity of water used per capita is not allowed to increase very materially beyond the present reasonable amount by reason of unnecessary use or waste.

It does not appear from the investigations that have thus far been made that there is any more favorable locality in which it is likely to be practicable to obtain an adequate supply of water for the town of Framingham, and the Board is of the opinion that the tests thus far made warrant the further investigations which you now propose to make.

Nov. 12, 1908.

To the Board of Water Commissioners of the Town of Framingham.

GENTLEMEN: — The State Board of Health received from you on Oct. 22, 1908, an application requesting the consent and approval of this Board to the taking of a water supply for the town of Framingham for domestic purposes from wells driven in the valley of Baiting Brook, so called, near a private way on the Perkins estate, between Pleasant and Capen streets, about three-quarters of a mile northwest of the railroad station at Framingham Center, accompanied by plans of the proposed works and a report by your engineer giving the results of further tests as to the quantity and quality of water obtainable from the ground in the locality made since the investigations of the early part of the year.

In response to this application the Board has caused the valley of Baiting Brook and the region about the wells to be examined by its engineer, and has examined the plans and report submitted and the information furnished by the results of the well-conducted tests that have been made in that locality. The earlier tests showed the presence of a stratum of coarse gravel beneath a deep layer of sand underlying a considerable area in the valley of Baiting Brook, and that water could be pumped very freely from the test wells, indicating that the conditions were favorable for obtaining a large quantity of water from the ground at that place.

The further tests have consisted in driving 52 additional wells in two groups on the northerly side of the brook, near where it is crossed by the private way leading from Capen Street to Pleasant Street, one group, including 22 of the wells, being located on the east side of the private way, and the other group, consisting of 30 wells, on the west side. The wells are located approximately in four lines 50 feet apart, and are 35 feet apart in the lines. Other wells were located at various distances from the main group for the purpose of observing the height of the ground water, and a pumping test was then made by pumping from the wells continuously for a period of fifteen days at a rate of a little over 1,000,000 gallons per day.

Samples of water were collected for analysis at frequent intervals during the test, and the results, taken in connection with samples collected at other times, indicate that the water, while somewhat hard, would be of good quality for all the purposes of public water supply.

The soil penetrated by the test wells was coarse and porous and yields water very freely. The quantity of water pumped during the test averaged a little over 1,000,000 gallons per day, an amount more than

60 per cent. in excess of the quantity of water now being used by the town; but the conditions for obtaining a large quantity of water from the ground in this locality were more favorable during the test than those which would obtain in actual operation at the end of a long dry season, and it is very doubtful, in the opinion of the Board, whether the quantity of water obtainable from the wells would, in such a season, be more than sufficient for the present requirements of the town.

It is probable that a larger quantity of water could be obtained if the number of wells were considerably increased and if they should be extended over a much wider area, and under those conditions a sufficient supply might be obtained from this source for present requirements and possibly for several years in the future, but it is unlikely that enough water can be obtained in this locality to supply the town for a very long period in the future unless the supply should be supplemented in very dry seasons with water from some other source.

In the opinion of the Board it is not advisable to construct works for taking water from this source until further investigation shall be made to determine whether the yield of ground water can be materially increased by extending the collecting wells, especially into the region above Capen Street, and whether, if it should be decided to build works for taking water from the valley of Baiting Brook, the supply can be adequately supplemented with water from some other source in case of need.

FRANKLIN.

AUG. 6, 1908.

To the Board of Water Commissioners of the Town of Franklin.

GENTLEMEN: — The State Board of Health received from you on July 31, 1908, the following communication for advice as to installing a permanent pumping station in connection with the new tubular wells near the northerly end of Beaver Pond: —

The board of water commissioners of the town of Franklin, Mass., is planning to install a permanent new pumping station near Beaver Pond, the water to be drawn from tubular wells located on land bordered by Beaver Pond and Mine Brook. There have already been driven in this locality 41 2½-inch tubular wells, having an average depth of approximately 33 feet. The majority of these wells penetrate a fairly fine stratum of sandy gravel, some of them encountering coarse porous gravel. Thirty-three of these 41 wells have been connected to 6-inch, 8-inch and 10-inch suction pipes in two groups, and the water from these two groups is brought together into a 12-inch suction main leading back to the present pumping station on the town side of Mine Brook. The board believes from its tests that there is an ample supply of water from these driven wells. The extreme length

of the 12-inch suction main to the present pumping station results in so high a vacuum on the suction main that the capacity of the available pumping engine has been and is severely taxed when running anywhere near the speed required to meet the demands of the town during hot and dry weather. The board believes that to give satisfactory and permanent service a new pumping station should be erected in the immediate vicinity of the above wells, where the increased vacuum due to the present long line of 12-inch suction main will be avoided. The town has already purchased the necessary 12-inch cast-iron pipe and specials for the extension of its forcemain down to the new location, but has been waiting for your final opinion as to the present condition and quality of the water, as shown by recent analyses, and for your advice as to the probability of its continuing to be satisfactory in the future both as to quality and quantity. Your opinion and your advice on these points are respectfully requested.

The Board has caused the locality to be examined by its engineer and has considered the results of analyses of samples of water from tubular wells and other sources in their neighborhood.

An examination of the analyses of the individual wells shows that the ground water of the wells near the easterly end of the line contains a considerable quantity of chlorine and nitrates, indicating that it has at some time been polluted, and it has not been very well purified in its subsequent passage through the ground before entering the wells. It is impossible to determine from the information thus far available the source of this pollution, which may be due to a deposit of organic matter in this locality at some previous time, or, possibly, to ground water which may find its way to the wells from a part of the village located at no great distance from them.

These wells yield water of such poor quality that, in the opinion of the Board, it is desirable to discontinue the use of all of the wells numbered from 1 to 13 inclusive.

In order to be able to discontinue the use of the wells indicated, it will be necessary to provide additional wells. The wells nearest Beaver Pond yield water of excellent quality, and the conditions appear to be favorable for obtaining water freely from the ground around the northwesterly end of Beaver Pond, beyond the limits of the present wells. Under the circumstances the Board would recommend that, before a change is made in the present pumping station, you make tests to determine whether an adequate supply of good water can be obtained in the location indicated.

The Board will assist you in further investigations by making the necessary analyses of water, and when the results are available will give you further advice in this matter.

GARDNER (STATE COLONY FOR THE INSANE).

JAN. 2, 1908.

To the Board of Trustees of the State Colony for the Insane, Gardner, Mass.,
DR. CHARLES E. THOMPSON, *Superintendent.*

GENTLEMEN: — The State Board of Health has considered your application for advice with reference to a proposed water supply for the State Colony for the Insane at Gardner, to be taken from the ground in the valley of a brook on the southerly side of a considerable swamp north of Beech Hill, and the plan and report of your engineer submitted therewith, and has caused the locality to be examined by its engineer and samples of water from test wells to be analyzed.

A short time before the application was submitted test wells had been driven in the locality indicated, and subsequently a pumping test was made by pumping continuously from 4 of the wells at a rate of about 60,000 gallons per day for a period of thirteen days, from November 18 to 30 inclusive. During this test samples of water drawn from the wells were sent to the laboratory of the Board for analysis, and the results show that it is of good quality for the purposes of a public water supply.

The wells are located in a small area of sandy land near the foot of Beech Hill, bordered on two sides by the swamp. The soil in this area consists of coarse sand extending to a depth of about 20 feet below the surface, beneath which is fine sand or clay. The soil of the land south and east of the wells appears to be too fine to permit the passage of any considerable quantity of water, and it is probable that the water entering these wells came largely from beneath the adjacent swamp.

The number of inmates and their attendants in this asylum is likely to continue to increase until the total is much larger than at present, and, judging from the quantity of water used at other insane hospitals in the State, the daily quantity of water required is likely to reach at least 100 gallons per person, and perhaps a larger amount. Under the circumstances it is important, in the opinion of the Board, to select if possible in the beginning a source of water supply that can readily be developed to yield as much as 150,000 gallons per day during a dry season.

The conditions for obtaining water freely from the ground appear to be quite favorable near the railroad about a quarter of a mile north of the locality in which the recent tests were made, and it is possible that an adequate supply of good water for the institution could be obtained in that locality. Favorable conditions are also found in the neighborhood of the railroad, about a mile east of the Westminster group of cottages.

The height to which water must be raised if taken from either of these localities, and especially the last one mentioned, will involve a considerable expense for pumping, and it would be desirable to obtain a supply from a source situated at a greater elevation if practicable. The elevation of the territory west and south of the institution is considerably higher than that toward the east, and it is possible that an adequate supply of good water could be obtained in that region within a reasonable distance.

The Board would recommend that the question of obtaining a water supply in the region south and west of the institution be given careful consideration; and, if it is impracticable to obtain a satisfactory supply there, it would be best, in the opinion of the Board, to make further tests near the Fitchburg Railroad, east of the institution, beginning in the locality above indicated.

GREENFIELD.

DEC. 3, 1908.

To the Board of Water Commissioners of the Town of Greenfield.

GENTLEMEN: — In response to your request of Nov. 19, 1908, for an examination of Green River to ascertain whether the use of that stream as a source of water supply for Greenfield can be continued with safety, the Board has caused the locality to be examined by its engineer and has examined the information furnished by maps of the region and records of analyses and other observations in previous years.

Green River drains a very sparsely settled area, containing 51.6 square miles, the greater part of which (37.1 square miles) is within the limits of the State of Vermont. There are two small villages within the drainage area, both situated in the valley of the stream, and a number of widely scattered farmhouses, most of which are located at long distances from the water works' intake.

The water, as shown by analysis, is nearly colorless, and while somewhat hard is in other respects of good quality for water-supply purposes. The stream evidently receives but little pollution, but on account of its rapid fall and other circumstances infective matters finding their way into the river, even in the remoter parts of the watershed, might be carried to the water works' intake within a comparatively short time, and in the opinion of the Board the source is an unsafe one from which to take water directly for water-supply purposes.

It is very important that the town secure, with as little delay as practicable, a source which will furnish an adequate quantity of good water for its requirements at all times, but the Board is unable to advise you definitely at present as to the most appropriate of the sources which appear to be available for an additional supply of water for the town

of Greenfield. The examinations of the region about the Green River and its tributaries in the neighborhood of the water works' intake and below show that the conditions are very favorable, so far as can be judged from surface indications, for obtaining water in large quantity from the ground by means of wells. A good ground-water supply would probably be less expensive and much more satisfactory in all respects than a supply from any surface source, and the Board recommends that tests be made at the most favorable places in this region to determine the character of the soil and quality of the ground water.

It is very important, in the opinion of the Board, that the investigations be made with as little delay as possible, since it is desirable that an adequate supply of good water be made available before another dry season. The investigations should be made under the direction of an engineer of experience in the selection of ground-water supplies, and the Board will assist by making the necessary analyses of water, and will give you further advice when the results of preliminary investigations are available.

Hadley (Well in North Hadley).

Sept. 25, 1908.

To the School Committee of the Town of Hadley, Dr. F. H. Smith, *Chairman.*

Gentlemen: — In response to your request for an examination of the water of a well in a school building at North Hadley, and advice as to its quality, the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water has evidently been considerably polluted and contains a larger quantity of organic matter than is found in good well waters. The school vault is located quite close to the well, and the Board recommends that the use of the water for drinking be prevented.

Hamilton (Well at Hamilton Park).

March 5, 1908.

To Mr. Edward B. Trumbull, *President, Hamilton Park Association, Salem, Mass.*

Dear Sir: — In response to your request of Jan. 21, 1908, the Board has caused the location of the new well at Hamilton Park to be examined by one of its engineers and samples of its water to be analyzed.

The analysis of the sample collected at about the time the application was received indicated that the water had been seriously polluted, and another sample was collected on February 13. The latter sample, taken under more favorable conditions, shows, nevertheless, that the water

has been at some time very seriously polluted and not thoroughly purified before entering the well, and in the opinion of the Board the water cannot be regarded as safe for drinking. There are sources of pollution at no great distance from the well, and it will be necessary, in order to obtain good water from the ground, to locate a well at a much greater distance from possible sources of pollution than the well from which the recent samples were taken.

MAY 7, 1908.

To Mr. EDWARD B. TRUMBULL, *President, Hamilton Park Association, Salem, Mass.*

DEAR SIR: — In accordance with your request of April 1, 1908, for an examination of a well recently driven in the neighborhood of the grounds of the Hamilton Park Association at Hamilton, and advice as to the quality of the water, the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water, though it has been at some time slightly polluted, is at present of good quality for drinking. It will probably continue to be safe for drinking if no buildings or other source of pollution shall be located nearer the well than at present.

HANSON (HANSON MANUFACTURING COMPANY).

OCT. 1, 1908.

To Mr. WILLIAM F. RUSSELL, *Treasurer, Hanson Manufacturing Company, 85 Ames Building, Boston, Mass.*

DEAR SIR: — Some time ago a communication was received from the agent of the Hanson Manufacturing Company, stating that it was proposed to introduce water from wells for manufacturing and domestic purposes in three factories and several dwelling houses situated in the town of Hanson, and requesting the advice of the Board as to the quality of the water, and the Board caused the locality to be examined, but was unable at that time to obtain a sample of water for analysis.

Recently a further examination of the locality has been made by one of the engineers of the Board, from which it appears that the water supply is drawn from 16 tubular wells, about 40 feet in depth, located in a peat bog but not far from the upland, about half a mile west of the Burrage station on the New York, New Haven & Hartford Railroad, and the Board has caused a sample of water from the wells to be analyzed.

The results of the analysis show that at the present time the water is of good quality for drinking and other purposes, and there appear to be no buildings or other possible sources of pollution in the im-

mediate neighborhood of the wells. In the opinion of the Board the water may safely be used for drinking while the conditions about the wells remain as at present. It is possible that the water of the wells may become affected in time by the presence of an excessive quantity of iron, which would make it objectionable for many purposes, as frequently happens when wells are located in a meadow or swamp covered with peaty soil, as in this case, but there are no marked indications that the water is likely to be affected in that way at the present time.

HAVERHILL (NEW ENGLAND DEACONESS ASSOCIATION).

FEB. 10, 1908.

To Miss MARY ANNA TAGGART, *Superintendent, New England Deaconess Association, Boston, Mass.*

DEAR MADAM: — In response to your request of Dec. 23, 1907, for an examination of the water supply of the Fresh Air Home at Haverhill, and advice as to its quality, the Board has caused the sources of supply used at that institution to be examined and samples of their waters to be analyzed.

The water of the well near the house shows evidence of sewage pollution, and contains a larger amount of organic matter than is found in a good well water, and in the opinion of the Board is not safe for drinking.

The spring east of the barn evidently receives surface drainage from the slopes about the barn. The analysis shows the presence of an excessive quantity of organic matter, and in the opinion of the Board the water is unsafe for drinking.

The reservoir from which the main supply is taken is supplied in part by surface water and in part by springs collected from a watershed of perhaps 20 acres of uninhabited woodland on the side of the hill north of the house. If the reservoir should be thoroughly cleaned out the quality of the water would doubtless be better than at present, but the water gathered into the reservoir is largely ground water, which is likely to deteriorate on exposure to light and be affected at times by an objectionable taste and odor.

The safety of the use of the water of this reservoir is dependent upon keeping the watershed above clear of pollution, and considering the evidence of pollution found upon the watershed at the time of a recent examination, the source cannot be regarded as a safe one from which to take water for drinking.

It would be practicable to cover the reservoir by enclosing the deeper portion, having a diameter of perhaps 20 to 25 feet, with a wall, of which the dam might form a part, thus forming a large well inside

the reservoir. The well should be made of as great a diameter and depth as practicable, so as to hold enough water to supply the quantity required during a dry period. If the dam still leaks and cannot be made tight, the bottom of the well and the side walls below the level at which the collecting drains enter should be made tight by covering the bottom with concrete and laying the walls with cement mortar, and the well should be carried down, if practicable, to a depth of 5 or 6 feet below the entrance of the collecting drains. The well should be covered with a wooden roof to prevent exposure of the water to light and danger of its pollution by visitors. The remainder of the reservoir outside of the wall should be filled with sand or gravel, and the drains entering the reservoir should be covered with sand to a depth of at least 4 feet, and so arranged that surface water cannot enter them without passing at least 4 feet through the ground. With these changes the water of this source would probably be safe for drinking.

The Board would recommend that a supply of good drinking water should be provided for this institution before the coming summer, and that the use of the present objectionable sources be discontinued.

Hingham (Spring of C. H. Leary).

Aug. 6, 1908.

To Mr. C. H. Leary, *South Weymouth, Mass.*

Dear Sir: — In accordance with your request of July 17 for an examination of a spring near the South Weymouth road in the southerly part of Hingham, from which it is proposed to sell water for drinking in Hingham and other towns, the State Board of Health has caused the locality to be examined and a sample of water from the spring to be analyzed.

The results of the analysis show that the water is naturally of good quality and safe for drinking. If it is to be used as proposed, the necessary provision should be made for protecting the water from pollution at the source and in the process of delivery to consumers.

Holyoke.

Under the authority of section 113 of chapter 75 of the Revised Laws, rules and regulations were made by the Board on Aug. 6, 1908, for preventing the pollution and securing the sanitary protection of the waters of Fomer Reservoir and its tributaries, used by the city of Holyoke as a source of water supply.

HOLYOKE (AMERICAN THREAD COMPANY).

APRIL 2, 1908.

To the American Thread Company, Holyoke, Mass., Mr. GEORGE H. MILLER, *Local Engineer.*

GENTLEMEN: — In response to your request for an examination of the water of a driven well, located near the bank of the Connecticut River at your Mill No. 5, the State Board of Health has caused the well and its surroundings to be examined by one of its engineers and samples of the water to be analyzed.

The results of the analyses show that the water contains a larger quantity of organic matter than is found in a good well water. The indications are that the water entering the well is derived largely by filtration from the canals and that it has not been thoroughly purified in its passage through the ground. The Board does not advise its use for drinking.

HYDE PARK (BECKER-BRAINARD MILLING MACHINE COMPANY).

FEB. 6, 1908.

To the Becker-Brainard Milling Machine Company, Hyde Park, Mass.

GENTLEMEN: — In response to your request of January 24 for an examination of the water of driven wells from which the drinking water supply used in your factory is obtained, and advice as to its quality, the Board has caused the wells and their surroundings to be examined by one of its engineers and a sample of their waters to be analyzed.

From the examination it appears that the supply of water is drawn from 3 tubular wells located in the rear of the factory and from 25 to 30 feet from Mother Brook. These wells are 2½ inches in diameter and are said to range in depth from 26 feet 10 inches to 28 feet 8 inches.

The results of the analysis of the water of these wells show that it is quite hard, and has been badly polluted and not subsequently thoroughly purified in its passage through the ground to the wells. The wells are located in a thickly populated region very close to Mother Brook, a stream which receives considerable pollution, and in the opinion of the Board they are not safe sources from which to take water for drinking.

LAWRENCE.

MARCH 24, 1908.

To Mr. ARTHUR D. MARBLE, *City Engineer, Lawrence, Mass.*

DEAR SIR: — The State Board of Health received from you on March 10, 1908, plans and specifications for the construction of a new filter, to replace the easterly section of the present open filter of the Lawrence water works, and subsequently a communication giving further infor-

mation relative to the proposed plans for enlarging and improving the works for filtering the water supply of the city of Lawrence, in which you indicate that after the reconstruction of the section of the old filter now under consideration it is probable that a new filter will be constructed north of the present filters, and that the remaining sections of the old filter will not be changed from their present form.

The plans now presented provide for a covered filter having a net filtering area of about .78 of an acre, to be constructed of concrete masonry on the site of the easterly section of the present filter. The filter is to be thoroughly underdrained with tile pipes and gravel, and the filtering material, as shown upon the plans, is to consist of sand taken from the present filter with such additional quantity of similar sand as may be necessary. The depth of sand, as shown on the plans presented, is to be 4.5 feet.

The water is to be applied to the filter through channels along the southerly side and the easterly and westerly ends, the channels being similar to those in the new filter recently completed. The filtered water is to be collected by underdrains similar to those in the new filter and discharge through a pipe-line into the old filter-gallery near the pumping station. Gates are shown on the main outlet pipe from the filter for controlling the rate of flow, and an opportunity is afforded for collecting samples of the effluent.

The Board has considered the plans and is of the opinion that the proposed filter will satisfactorily purify water for the supply of the city of Lawrence, provided the filter is operated at rates no greater than have been found to give efficient results in the filtration of the water of the Merrimack River, and, on the basis of ability to purify the water, the Board approves the plans presented.

The Board would suggest that means be provided for measuring the rate of flow through this filter, and the filter recently constructed, and it will, of course, be necessary to provide means of wasting the water of this new filter for a time after its completion, until it comes into effective operation.

Lenox.

July 2, 1908.

To the Lenox Water Company, Lenox, Mass.

Gentlemen: — The State Board of Health received from you on May 13, 1908, a petition for the consent and approval by this Board to the taking, by purchase or otherwise, of certain lands, with buildings thereon, and rights of way within the watershed of the Lenox Company's large storage reservoir, in the southwesterly part of the town of Lenox and the southeasterly part of the town of Richmond, for preserving the purity of the water used by said water company for the supply of the

town of Lenox, under the provisions of chapter 157 of the Acts of the year 1908, accompanied by a plan and description of said lands.

In response to this petition the Board gave a hearing at its office, Room 141, State House, on Thursday, June 4, 1908, at 11 A.M., after advertising said hearing in the "Berkshire County Eagle" and the "Pittsfield Journal," newspapers circulating in said towns of Lenox and Richmond. At this hearing no person appeared to oppose the petition of said water company, and the Board, after consideration, voted to authorize the Lenox Water Company to take so much of the lands now or formerly of George Dunbar, Samuel Dunbar and the Root estate, with buildings thereon, shown upon a plan filed with said petition, entitled "Water Shed of Lenox Water Co.," and described in your petition, as lie within the watershed of the large storage reservoir of the Lenox Water Company, in the southwesterly part of the town of Lenox and the southeasterly part of the town of Richmond.

The description of the lands presented in your petition, of which the taking of so much as lies within the watershed of the Lenox Water Company's large storage reservoir is herein authorized, is as follows: —

Description of Parcel of Land belonging to George Dunbar.

Beginning at a point in the east line of the watershed of the Lenox storage reservoir and in the south line of a highway leading from Lenox to Richmond and about 25 feet west of the northwest corner of land of one Blake. Thence in a generally southwesterly direction in the said east line of the watershed about 1,010 feet to a point in the north line of land of the Root Estate. Thence north 85° 35′ west about 1,025 feet in the north line of land of said Root Estate. Thence north 9° 10′ east in the west line of land of Shotter 110 feet. Thence north 89° west in the north line of land of said Shotter about 1,809 feet. Thence north 10° 50′ east about 865 feet to the south line of said highway. Thence north 85° 40′ east in the south line of said highway about 1,520 feet. Thence crossing said highway north 10° 40′ east about 50 feet. Thence north 10° 40′ east in the east line of Lenox Water Company land about 465 feet. Thence south 88° 20′ east in the south line of said Co.'s land about 655 feet to the west line of a highway leading from the first mentioned highway to Pittsfield past the residence of Samuel Dunbar. Thence south 88° 20′ east crossing said highway about 50 feet. Thence south 88° 20′ east in the south line of said Co.'s land about 670 feet to the northwest corner of parcel of land now or formerly of one Butler. Thence south 4° 30′ east in the west line of said Butler about 240 feet. Thence in a generally southerly direction in the aforementioned east line of the watershed about 480 feet to a point on the north side of the highway leading from Lenox to Richmond about 170 feet west of the southwesterly corner of land of one Roach. Thence in a southerly direction along the said east line of the watershed crossing said

highway about 55 feet to the place of beginning. Containing, not including roads, about 83.8 acres. The above courses are magnetic. Variation 10° 30′ west.

Description of Samuel Dunbar Land in Lenox, Mass.

Beginning at a stone bound at an angle in the town lines of said Richmond and said Lenox, said town corner being about 500 feet southerly from said Samuel Dunbar's house. Thence north 6° 25′ in said town line about 415 feet to a highway leading past Samuel Dunbar's house towards Pittsfield. Thence in the same course across said highway about 90 feet. Thence the same course along said town line about 215 feet to the west line of the watershed of the Lenox storage reservoir. Thence in a generally northeasterly direction along said west line of the watershed about 1,410 feet to a point in the south line of land of Bacon Estate and one Andrews. Thence 79° east along the south line of land of Bacon Estate and one Andrews about 840 feet. Thence north 21° 25′ east about 1,205 feet to land of the Richmond Iron Company. Thence south 80° 5′ east about 1,170 feet in the south line of land of said Richmond Iron Co. Thence south 11° 20′ west in the west line of land now or formerly of one Powers about 1,215 feet to the northwest corner of land known as the Minister Lot. Thence south 13° west about 2,490 feet to the southwest corner of said Minister Lot. Thence south 25° 35′ west about 930 feet in the north line of land of said Water Company. Thence north 80° 20′ west crossing said highway about 2,665 feet, and in the north line of land of said Water Company to a point in the east line of a parcel formerly of one Barnes, and now of said Water Company. Thence north 10° east in the east line of land of said Water Company and land of one Barnes about 1,175 feet to a point in the aforementioned west line of the watershed. Thence in a generally northeasterly direction in said west line of the watershed about 235 feet to the town line between Lenox and Richmond. Thence south 79° 20′ east in said town line about 420 feet to the place of beginning. Containing 231.1 acres be the same more or less.

Description of Samuel Dunbar Land in Richmond, Mass.

Beginning at a stone bound at an angle in the town line between Richmond and Lenox aforesaid, said corner being about 500 feet southerly from Samuel Dunbar's house. Thence north 6° 25′ east in said town line about 415 feet to the south line of the highway leading past Samuel Dunbar's house towards Pittsfield. Thence the same course about 90 feet across said road, thence same course about 215 feet to a point in the west line of the watershed of the Lenox storage reservoir. Thence in a generally southwesterly direction in said west line of the watershed about 800 feet to the town line between Lenox and Richmond. Thence south 79° 20′ east about 420 feet in said town line to the place of beginning. Containing 2.64 acres be the same more or less. The above courses are magnetic. Variation 10° 30′ west.

Description of Root Estate Parcels of Land.

The first parcel is south of a highway leading from Lenox to Richmond passing near the storage reservoir of the Lenox Water Company. Beginning at a point in the southerly side of said highway at the northeast corner of the parcel herein described, and also northwest corner of land of George Dunbar. Thence South 10° 50′ West in the west line of said George Dunbar's land about 865 feet. Thence the following courses and distances in the line of land of one Shotter: South 80° West about 211 feet: South 10° 45′ West 323 feet: South 88° 20′ West 343 feet: North 88° 40′ West 96 feet. Thence North 37° 35′ west about 605 feet to a corner of land belonging to the Lenox Water Co., and south of the dam of the said storage reservoir. Thence north 59° 40′ east in the said Water Co.'s line about 1,030 feet to a stone bound. Thence north 10° 25′ east 333 96/100 feet in the said Water Co.'s line to the south line of the aforementioned highway. Thence easterly in the south line of said highway about 400 feet to the place of beginning. Containing 18 4/10 acres be the same more or less. The above courses are magnetic. Variation 10° 30′ west.

Second Parcel.

Beginning in the southerly line of aforementioned highway at the northwest corner of land of said Water Company. Thence south 9° 35′ west in the west line of said Water Co.'s land about 737 feet to a stone monument. Thence south 39° 30′ east in line of land of said Water Company about 330 feet. Thence south 66° 45′ west about 410 feet. Thence north 27° 25′ west about 1,040 feet to the south line of the aforementioned highway. Thence easterly in the south line of said highway about 830 feet to the place of beginning. Containing 12¼ acres be the same more or less. The above courses are magnetic. Variation 10° 30′ west.

Third Parcel.

Beginning at a stone bound in the town line between Richmond and Lenox and in the northerly line of the aforementioned highway. Thence north 9° 35′ east in the said town line and in the east line of land of one Andrews about 1,335 feet to a point in the west line of the watershed of the Lenox storage reservoir. Thence in a generally northeasterly direction in said west line of the watershed about 1,450 feet to a point in the south line of land of one Barnes. Thence south 81° 20′ east about 300 feet to the west line of land of said Water Company. Thence south 9° 50′ west about 2,170 feet in the west line of land of said Water Company. Thence the following courses and distances in line of land of said Water Company: North 59° 50′ west about 195 feet. South 28° 25′ west about 200 feet. South 7° 50′ west about 90 feet to the north line of said highway. Thence north 83° 5′ west in the north line of said highway about 930 feet to the place of beginning. Containing 51.6 acres be the same more or less. The above courses are magnetic. Variation 10° 30′ west.

Nov. 12, 1908.

To the Lenox Water Company, Lenox, Mass.

GENTLEMEN: — In response to your communication of Nov. 10, 1908, relative to taking water from Laurel Lake in Lee as a temporary supply for the town of Lenox, made necessary by the exhaustion of your present sources of supply, the Board has caused an examination of Laurel Lake and its surroundings to be made by one of its engineers and has examined the results of analyses of its waters.

The results of the examination show that the watershed contains few buildings or other possible sources of pollution, and the water, though hard, is in other respects of good quality for domestic purposes.

Laurel Lake appears to be the best available source from which to take water for the supply of the town under the present emergency, and the Board approves its use for that purpose.

LYNN.

JAN. 15, 1908.

To the Public Water Board of the City of Lynn.

GENTLEMEN: — The State Board of Health received from you on Dec. 31, 1907, the following communication, submitting the results of investigations for improving the water supply of the city and a general plan of the work proposed: —

In accordance with chapter 479 of the Acts of 1907 of the Legislature, we submit herewith an abstract of the full report upon our water supply made by our engineer, Mr. William S. Johnson. We have decided to adopt scheme B, that is, filtration. Mr. Johnson will furnish detailed results of the investigations and full plans of the work proposed.

The application was accompanied by a report of your engineer giving a brief summary of the conclusions reached as the result of investigations carried on during the year 1907, and a general plan showing the location of the proposed filters and other works, and subsequently the full report of your engineer was presented.

The plans presented provide for the filtration of the water before it is supplied to the city through 6 sand filters having an aggregate area of 3 acres, to be located upon the city farm; for the drainage of swamps on the watersheds of the ponds; and for pumping the water of Saugus River into Hawkes Pond in order to avoid flowing the extensive meadows above Montrose, which is necessary under existing conditions if water is to be diverted into Hawkes Pond by gravity through the present canal and conduit. It is proposed to omit for the present the construction of the conduit or pipe line designed for conveying the water from Saugus River to the upper end of Walden Pond.

The Board has considered the application and the report and plan

submitted therewith, and concludes that the proposed plans will, if carried out, provide a satisfactory water supply for the city of Lynn, and the Board approves the general scheme presented, known as scheme B, which provides for filtering all of the water supplied to the city through sand filters to be located on the city farm.

The area of filters which it is proposed to provide will be sufficient for the requirements of the city in the beginning, but after a few years' use either the rate of filtration will have to be increased or the area enlarged in order to provide for the increasing requirements of the city. It seems to the Board undesirable to operate filters for the purification of this water at rates much higher than those which have been found to be successful in the filtration of polluted waters in this State, and the Board would advise that the filters be not operated at a rate materially greater than 2,500,000 gallons per acre per day.

The Board believes it important to provide for the storage of the water of Saugus River for as long a time as practicable before it is supplied to the city, and for this reason it is desirable that the water discharged from that stream into Walden Pond should be introduced at some point remote from the dam, instead of discharging it at the dam, as at present. The Board recognizes that there might be economy in making changes in the present works for conveying, storing and pumping water, and, under the circumstances, deems it reasonable to postpone the adoption of a definite plan for dealing with this question until a further study can be made. It is important, however, in the opinion of the Board, that this question of the storage of the water delivered from Saugus River be taken up without delay, and a definite plan selected and carried out as soon as practicable.

The improvements proposed by draining the swamps on the watershed and avoiding the flooding of the swamp above the intake at Montrose will tend to reduce the color of the water, and are desirable measures to carry out in connection with the other proposed improvements in the water-supply system of the city.

The act under which the present plans are presented requires the submission of plans for the proposed conduits, reservoirs, pipe lines, filters and other works for improving the water supply of the city of Lynn to this Board for its approval; and the Board would suggest that when the final detailed plans of the proposed works have been prepared, they be submitted for the consideration of the Board before construction is begun.

Nov. 12, 1908.

To the Public Water Board of the City of Lynn.

GENTLEMEN: — The State Board of Health received from you on Oct. 15, 1908, an application submitting a report outlining a plan for

enlarging and improving the water supply of the city of Lynn, in compliance with the provisions of chapter 610 of the Acts of the Legislature of the year 1908, entitled "An Act to extend the time within which the city of Lynn shall enlarge and improve its water supply."

Plans for improving the quality of the water supplied to the city of Lynn have been under consideration for many years. In 1898 the Public Water Board recommended a system of filtration similar to that of Lawrence, and in 1901 an act of the Legislature, giving authority to the city of Lynn to take water from the Ipswich River and to make an additional water loan, contained a provision giving the city power to establish works for filtering its existing and any additional water supply, and to apply to that purpose any portion of the loan authorized by that act.

In 1905 and again in 1906 the objectionable character of the water supplied for public use in the city of Lynn was reported to the Legislature, and in 1906 an act was passed directing the State Board of Health and the water board of the city of Lynn to investigate and prepare a plan for increasing and improving the water supply of the city. The results of the investigations were reported to the Legislature in 1907, and recommended slow sand filtration for the purification of the water. An act was then passed (chapter 479 of the Acts of the year 1907) directing the city to provide an adequate supply of good water for all the requirements of the city, the works to be begun within one year and completed within three years after the passage of the act. The act did not, however, require that the works should be built in accordance with the recommendations, but authorized the city to make still further investigations upon enlarging and improving its water supply. A further investigation was accordingly made and the results presented in two plans, which were submitted to the State Board of Health for approval on Dec. 31, 1907, as required by the provisions of the act above mentioned, and the plan for filtering the water, having been found to be the least expensive and most efficient of those submitted, was recommended by the Public Water Board and approved by the State Board of Health on Jan. 14, 1908.

In order to give the city opportunity for still further investigations and consideration of the question, the Legislature of 1908, by the provisions of chapter 610, extended the time within which the city should enlarge and improve its water supply for a period of one year, and ordered the plan approved by the State Board of Health on Jan. 14, 1908, to be recommitted to the city.

Since the passage of that act further investigations appear to have been made, both by the water board and city council.

The plan now presented for the approval of this Board, under the

provisions of chapter 479 of the Acts of the year 1907, as amended by chapter 610 of the Acts of the year 1908, is outlined in your report to the mayor and city council of Lynn under date of Aug. 15, 1908, as follows: —

1. Drain the swamps on the watershed of our four ponds to prevent the soaking up of so much vegetable matter and color.

2. Place a pump at Montrose, lifting the water about 6 feet and discharging it into the present canal, through which it will flow to Hawkes Pond. The purpose of this pump is to obtain water from Saugus River without the necessity of raising the level of the river and flooding large meadow areas, which must now be done to get the water high enough to flow into the canal. Flooding the meadows causes the water to take up large quantities of vegetable matter and color, and, further, is only permitted during winter months, whereas it may be desirable to take the water at other times.

3. Place a pump at the lower end of Hawkes Pond, carrying the discharge pipe across the turnpike to the northern end of Walden Pond. This pump to simply take water from Hawkes to Walden Pond; the advantage of this arrangement being as fully outlined above.

Each of these pumping equipments would be housed in a small, inexpensive, fireproof building, and the pumps will probably be driven by electric motors, taking current either from our own generator at the Walnut Street pumping station or from the station of the Lynn Gas and Electric Company, depending on which method proves cheaper.

4. From Walden Pond the water would flow by gravity through the existing pipes and tunnel to Birch Pond, thence through Birch and directly into the filters.

5. The water from Breed's Pond would flow to the filters through the present 22-inch pipe, which now runs from Birch Pond to the pumping station.

6. Slow sand filter beds in six divisions, and with an aggregate area of 3 acres, would be located at the lower end of Birch Pond, on the cricket grounds. The water, after passing through the filters, would be collected in a clear-water basin of about one and three-quarter million gallons' capacity.

7. From the clear-water basin the water would flow by gravity to the Walnut Street pumping station through the present pipes. A few years hence a new pipe would be needed for about half of the way, as by that time the consumption will probably be such that the present 30-inch main would not be able to carry the water required. From the pumping station the water will be pumped as now to the reservoir and stand-pipe on Pine Hill, from which it is distributed by gravity to the city.

Attached to and forming a part of this report is a plan showing the proposed works, including a pumping station near the Saugus River at Montrose to raise the water of the river into the canal leading to

Hawkes Pond, a force main through which it is proposed to deliver the water into the northerly arm of Walden Pond and filtration works below Birch Pond, with pipe lines connecting with the present pumping station and distributing system. The plan also shows a proposed future pumping station at the Ipswich River near the mouth of Will's Brook, and the line of a force main through the valley of Will's Brook to Beaver Dam Brook, but your report mentions several other ways by which the water of the Ipswich River can be utilized in connection with the present works when a future supply becomes necessary, some one of which may be found better than the method indicated upon the plan, and you do not recommend the definite selection of a plan for taking water from the Ipswich River at the present time.

You also present an estimate of the cost of the proposed works, amounting to $313,900, and you estimate the cost of operating the filters at $6,000 per year.

The plan in general is similar to scheme B, so called, — the plan recommended by your board last year when plans for the enlargement and improvement of the water supply of the city of Lynn were presented to this Board on Dec. 31, 1907, under the provisions of chapter 479 of the Acts of the year 1907.

The act of 1908, chapter 610, already referred to, provides that the State Board of Health shall give a hearing to the city council of Lynn upon the plans presented by your board, if requested to do so on or before the 20th of October in the year 1908, and a request having been made by the city council, through the city solicitor, for such hearing within the time prescribed, the Board, after conference with the city solicitor, gave a hearing to the city council of Lynn at its office, on Thursday, Nov. 5, 1908, at 11 A.M. At this hearing the city council of Lynn was represented by the mayor, city solicitor, city engineer and members of the city council.

It was stated at the hearing that the city council was opposed to the adoption of the plan before the board, but no definite alternative plan was presented. Certain advantages were urged for scheme A, so called, submitted by your board with scheme B for the consideration of this Board in December last, the selection of which was not recommended, and reference was made to the possibility of purifying the Lynn water satisfactorily by treatment with ozone. Reference was also made to the possibility of enlarging the storage capacity of the system by raising the dam of Breed's Pond. It was finally urged that the financial condition of the water department is not as satisfactory as published reports would indicate, and that expenditures for enlarging and improving the water supply should be kept within the smallest practicable limit.

The Board has considered the plans presented and the suggestions and considerations urged by the city council at the hearing on November 5.

The Board considered carefully the provisions of scheme A and the results likely to be attained under it in the enlargement and improvement of the water supply of the city, and found that by the estimates presented it would not only cost considerably more than scheme B, but that the protection and improvement of the water supply that could be secured under it would be in no respect equal to the results that would be secured by the adoption of scheme B. Such further improvement as might be obtainable under scheme A by the enlargement of Breed's Pond, as suggested at the hearing, would, in the opinion of the Board, be inconsiderable, while the cost of enlarging Breed's Pond, with attendant changes in the system, would evidently be large and add materially to the cost of scheme A.

That the numbers of bacteria in a polluted water can be materially reduced by treatment with ozone is a fact that has long been known, and attempts have been made experimentally, and also in practice, in several places to purify water supplies by that method. The results do not show that that method under favorable conditions can be depended upon to remove bacteria or color from water more efficiently than slow sand filtration, and some form of filtration is a necessary part of the ozone process if used for the purification of water containing much color and organic matter, such as that of Lynn. Moreover, the efficiency of the process is dependent upon the certainty of an adequate and never-failing supply of electric power, and upon competent expert supervision. The cost of operation has thus far been found to be great, and an adequate guaranty of the performance of such a system is obviously impracticable. In the opinion of the Board the efficiency of this process, as shown by the most recent experiments and experience, has not been such as to enable the Board to approve its use for the purification of the water supply of the city of Lynn.

The plan now presented for the approval of this Board is similar, as already stated, to scheme B, presented last year, the important changes being that the water of Saugus River, after passing through Hawkes Pond, will all be pumped into the northerly arm of Walden Pond, whence it will flow to Birch Pond, from which it will be drawn to the filters, thus insuring the passage of the most polluted water of the present sources through the available storage reservoirs before delivery to the filters.

It is also proposed to change the location of the filters from the proposed site at the city farm to a location below Birch Pond, the reason

for the change apparently being that the lands at the city farm had been used many years ago for the interment of persons who had died of contagious disease. Except for the change in the location, the plan of the filters is similar to that proposed and approved by this Board last year; that is, it is proposed to construct 6 sand filters, of the type used at Lawrence, having an aggregate area of 3 acres. With a filtration plant of that size the rate of filtration with the present consumption of water in Lynn will be about 2,400,000 gallons per acre per day, allowing that one filter will be constantly out of use for cleaning, repairs, etc. With the increasing consumption of water the rate of filtration will become greater.

The water which will be applied to the filters at Lynn, under the plan now presented, will ordinarily contain small numbers of bacteria, and experiments upon the filtration of similar waters give no reason to doubt that the Lynn water under the proposed plan can be purified at a rate as high as 4,000,000 gallons per acre per day, and possibly higher. The above remarks apply to the removal of bacteria only. As regards the removal of tastes and odors, the difference in efficiency between rates of 2,400,000 and 4,000,000 gallons per acre per day would not be material.

Under the circumstances, the area of filters which it is proposed to construct in the beginning is, in the opinion of the Board, a reasonable one, and an enlargement of the area will not be necessary until the available capacity of the sources now used has been reached.

The Board, acting under the provisions of chapter 479 of the Acts of the year 1907, and chapter 610 of the Acts of the year 1908, approves the plan presented for the enlargement and improvement of the water supply of the city of Lynn as outlined in your report, dated Aug. 15, 1908, and shown on the plan annexed thereto, except the pumping station at the Ipswich River and force main through the valley of Will's Brook to Beaver Dam Brook, shown on that plan, — the selection of a definite plan for taking water from the Ipswich River being left for future consideration, as suggested in your report.

LYNN (WELL IN MEADOW PARK).

AUG. 6, 1908.

To the Board of Health of the City of Lynn.

GENTLEMEN: — In response to your request of July 18 for an examination of the water of a well in Meadow Park in Lynn, and advice as to its quality, the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water has been at some time

badly polluted, but subsequently quite well purified in passing through the ground before entering the well; and in the condition in which it was found at this time it was probably safe for drinking. The water is hard, however, and to this extent an undesirable drinking water, and a change in the conditions affecting its pollution may at any time make it unsafe for drinking; and the Board recommends that its further use for drinking be discontinued.

Lynn (Y. M. C. A.).

Jan. 14, 1908.

To Mr. Dwight L. Rogers, *General Secretary, Y. M. C. A., Lynn, Mass.*

Dear Sir: — In response to your request for an examination of the water of a tubular well 290 feet deep, situated at the corner of Market and Tremont streets in Lynn, and advice as to its use for drinking, the State Board of Health has caused the source of supply to be examined and several samples of its water to be analyzed.

The results of the analyses show that the water contains a somewhat larger quantity of organic matter than is found in good well waters, but in its present state it is probably safe for drinking. The circumstances of its location are such that there is much danger that the quality of the water will deteriorate after a longer or shorter period of use, and the Board would recommend that the water, if used for drinking, be analyzed from time to time and its use discontinued if its quality deteriorates.

Manchester.

Nov. 11, 1908.

To the Board of Water Commissioners of the Town of Manchester.

Gentlemen: — The State Board of Health received from you on September 4 a petition for the approval by this Board of the taking of the waters of Gravel Pond and Round Pond and the waters which flow into and from the same, and certain lots of land and rights of way in the towns of Manchester and Hamilton, for the purpose of holding, storing, purifying and preserving said waters, the location of said lands and rights of way being shown on a map submitted with your application, and in response to this petition has caused the locality to be examined by its engineer and has examined the plan presented.

On the lands which it is proposed to take, two lots, numbered on the plan parcels 1 and 2, are located 800 feet or more north of the junction of Pleasant and Pine streets in Manchester, and are to be used for the purpose of constructing a new distributing reservoir for your water-supply system. Parcel No. 3, situated at the southerly end of Gravel Pond, and including .55 of an acre, is to be used for the location of a pumping

station, and appears to be suitable and necessary for that purpose. Parcel No. 4 is located in part between Gravel and Round ponds and in part along the northwesterly side of Round Pond, and includes the brook flowing between the ponds, the outlets of Round Pond and certain gravelly areas containing soil suitable for the purification of water. The rights of way which it is proposed to take are chiefly existing private roadways, which are necessary to give access to the ponds and lands which the town proposes to take.

The Board has already advised, in a communication dated Dec. 5, 1907, that in its opinion the use of water from Gravel Pond, supplemented by Round Pond, is the best practicable method of increasing the water supply of Manchester, and, having considered the plans now presented, hereby approves the taking of the waters of Gravel Pond and Round Pond, as proposed in your petition, and approves also the taking of the lots of land and rights of way shown on said plan, which is entitled "Plan of lands, waters and water rights for an additional supply of water for the town of Manchester, dated August 1st, 1908, Raymond C. Allen, Civil Engineer."

A description of the lands, with rights of way, the taking of which is hereby approved, is appended.

MARBLEHEAD.

MAY 7, 1908.

To the Board of Water Commissioners of the Town of Marblehead.

GENTLEMEN: — The State Board of Health received from you on March 4, 1908, an application for advice relative to enlarging and improving the water supply of the town, accompanied by a report and plan presented by your engineer, Mr. William S. Johnson of Boston, describing the proposed works.

The plan submitted provides for purifying the water of the present sources of supply, which is now obtained wholly from 2 large wells located near Forest River, known respectively as wells Nos. 1 and 2, — which has always been affected by the presence of an excessive quantity of iron, — by filtering the water through sand filters, to be constructed in the neighborhood of the pumping station, and for enlarging the supply by introducing water from tubular wells to be located in Thompson's Meadow, so called, situated in the valley of Forest River about a mile above the wells.

The plan for removing the excess of iron from the water provides for the construction of 2 sand filter beds having an aggregate area of 8,712 square feet, consisting of 2 feet in depth of sand above 12 inches of gravel containing underdrains. It is proposed to discharge the under-

drains into well No. 1, from which the water will be drawn to the pumps, as at present. The rate of filtration during the time of maximum consumption in summer, when the quantity used is over 1,000,000 gallons per day, would be between 5,000,000 and 6,000,000 gallons per acre per day when both beds are in operation, and during the winter season, when the consumption is about 500,000 gallons per day, the rate of filtration would be about 2,500,000 gallons per acre per day. On account of the fact that the water to be filtered is a ground water, having a comparatively high temperature in winter, and of the further fact that the rate of filtration in winter would be a comparatively slow one, it is thought best to build open filters, and thus effect a considerable saving in cost of construction, but the aerating devices and settling tank will be covered.

The Board has caused the locality to be examined by its engineer and has carefully considered the plans presented. The experiments upon the filtration of the water of your present sources of supply have shown that the water can be efficiently purified by filtration through sand, after thorough aeration, at a rate of 5,000,000 gallons per acre per day, and possibly at a higher rate, and in the opinion of the Board the water can be efficiently purified by a filter of the size proposed if constructed of sand similar to that used in the experiments. Covered filters could, in the opinion of the Board, be operated more easily than open filters both in summer and winter, but their cost would be much larger than that of open filters, and it is likely that, with proper care, the water can be purified efficiently at all seasons by means of open filters, as now proposed.

Whether the filtered water would be unfavorably affected by discharging it into well No. 1 cannot be determined definitely without actual trial. The water supplied to the town comes chiefly from well No. 2, and has always been affected by an excessive quantity of iron. This water has been supplied to the town by passing it through well No. 1, so that the character of the water of the latter well is not definitely known. It was not, however, affected by an excessive quantity of iron before water was introduced from well No. 2, and it is probable that if the water of the latter well should be diverted, or purified as proposed, the quality of the water of well No. 1 would become satisfactory so far as the amount of iron present is concerned, though some time might elapse before the effect of the iron introduced would be removed.

The quantity of water obtainable from the 2 large wells from which the town is now supplied has thus far been sufficient for all the requirements of the town, but the water of well No. 1 — situated in the low

ground near the river — is evidently becoming affected by the infiltration of sea water, and its quality is likely to become objectionable unless the draft is reduced. If this well is used as a collecting and storage basin for filtered water the level of the water can be kept sufficiently high to prevent further deterioration from this cause, but the yield of the well, which does not probably exceed 125,000 gallons per day in the drier portion of the year, is likely to be reduced thereby.

During the summer of 1907 the water of well No. 2 was not seriously depleted by the heavy draft of that period. The reduced draft on well No. 1 that will be necessary in the future, and the increase in the consumption of water in the town, are likely to make it necessary to draw more water from well No. 2 in the future than has hitherto been the case, and it is probable under the circumstances that an additional supply will very soon be found necessary.

The tests made in Thompson's Meadow have shown that a large additional supply could undoubtedly be obtained from the ground in that region, and the water, though harder than is desirable, is likely to be of satisfactory quality for domestic purposes if mingled with the water of the present sources after filtration; and in the opinion of the Board wells in Thompson's Meadow would be an appropriate source from which to obtain an additional supply for the town.

The plan presented appears on the whole to be the best practicable method of enlarging and improving the water supply of Marblehead and the only practicable plan by which an independent supply of good water can be obtained by the town at a reasonable expense. The quantity of water obtainable under this plan is likely to be sufficient for the town for several years in the future and the quality satisfactory, but the growth of population in the neighborhood of your present sources and of Thompson's Meadow is likely in time to have an unfavorable effect upon the quality of the water of these sources, and it is desirable that the town control a considerable area of land in the neighborhood of its sources of supply in order to protect their purity.

Medway.

Feb. 6, 1908.

To the Committee on Water Supply of the Town of Medway.

Gentlemen: — The State Board of Health received from you on Jan. 8, 1908, an application for advice with reference to a proposed water supply for the town of Medway, in which you state that tests have been made for a ground-water supply in several localities in the town, and that the most favorable conditions have been found in the low land north of the railroad station, where 2 test wells have been driven,

samples of water from which have been sent in for analysis, and you request the advice of the Board as to the probable quantity and quality of water to be obtained from wells in that vicinity.

The Board has caused the locality to be examined by one of its engineers and samples of water from the test wells to be analyzed, and has considered the information presented.

The wells — one of which (No. 8) was located 1,300 and the other (No. 9) 900 feet north of the railroad — penetrated porous soil, from which water could be drawn quite freely, and the tests as a whole are favorable for obtaining a sufficient supply of water for Medway from the ground in this locality; but the quality of the water, as shown by the analyses, seems likely to be affected by the pollution of the ground water in and about the village; and in order to obtain water of good quality in this region it would be necessary to locate the collecting works at a considerably greater distance from the village than the most northerly of the 2 test wells. Much of the soil in this region appears to be coarse and porous, judging from surface indications, and it is likely that favorable conditions for obtaining water from the ground can be found at a sufficient distance from the village to avoid pollution therefrom, but there is much swamp in this region, and further tests will be necessary before a location can be definitely selected.

While the conditions appear to be favorable for obtaining a sufficient supply of water for Medway from the ground in the region north of the village of West Medway, it is nevertheless desirable, in the opinion of the Board, that further tests be made in this and other places before the works are finally located, and that legislation be secured which will enable the town to obtain a water supply either from any source within its limits or from the region south of the Charles River within the limits of the town of Franklin, where conditions are found, especially near Populatic Pond, which appear to be favorable for obtaining an adequate supply of good water within a reasonable distance of the town, in order that the town may be able to secure the source which further investigations may show to be the best.

Middlefield.

Dec. 3, 1908.

To the Committee on Water Supply of the Town of Middlefield.

Gentlemen: — In response to a request from your engineer for an examination of a small stream located on the easterly side of the hill about half a mile northeast of the village of Middlefield, and advice as to its use as a source of water supply for the village, the Board has caused the locality to be examined by one of its engineers and a sample of the water to be analyzed.

The results of the analysis indicate that the water of the proposed source would be of good quality for water-supply purposes, but the quantity of water flowing in the stream during the very dry weather of the past season was very small, and it is doubtful whether the yield would be sufficient for the requirements of the village in the summer season. It appears to be practicable, by locating works about half a mile west of the proposed source, from 500 to 1,000 feet north of the highway leading from Middlefield to Peru and a little less than half a mile northwest of the village, to collect the flow of water from a much larger area of watershed than at the locality proposed in your application. The distance of this place from the village is but little greater than the source now proposed, and there is no reason to doubt that the quality of the water would be satisfactory if collected and stored without exposure to light. It is necessary, however, to avoid taking water from the stream which flows northwesterly from the neighborhood of the village.

The Board recommends that investigations be made of the practicability of obtaining water in sufficient quantity for the requirements of the village in the locality described, and the Board will give you further advice in the matter when you have the results of further investigations to present.

Milton (Well of Thomas Craig).

Nov. 5, 1908.

To Mr. A. W. Draper, *Secretary, Board of Health, Milton, Mass.*

Dear Sir: — In response to your request of October 9 for an examination of the water of the well of Thomas Craig, Horton Place, Milton, which appears to be the sole supply of water for several families, the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

There are a number of sources of pollution in the vicinity of the well, and the results of the analysis show that the water is badly polluted by sewage. The Board recommends that the further use of this well be prevented.

Montague (Turners Falls Fire District).

Under the authority of section 113 of chapter 75 of the Revised Laws, rules and regulations were made by the Board, on June 4, 1908, for preventing the pollution and securing the sanitary protection of the waters of Lake Pleasant and its tributaries, used by the Turners Falls Fire District in the town of Montague as a source of water supply.

MONTAGUE (LAKE PLEASANT WATER SUPPLY DISTRICT).

AUG. 6, 1908.

To the Board of Water Commissioners of the Lake Pleasant Water Supply District in the Town of Montague.

GENTLEMEN: — The State Board of Health received from you on July 9, 1908, an application requesting its approval, under the provisions of chapter 449 of the Acts of the year 1908, of the use of water from the water works of the Turners Falls Fire District for the supply of the Lake Pleasant Water Supply District, and in response to this application the Board has caused Lake Pleasant, the source of supply of the Turners Falls Fire District, to be examined by one of its engineers and has examined the results of numerous analyses of its waters.

The quantity of water obtainable from Lake Pleasant is ample, in the opinion of the Board, for all the requirements of the Lake Pleasant Water Supply District in addition to the population of the other districts now supplied from that source.

The water supplied from Lake Pleasant is of good quality for all the purposes of a public water supply. There are several houses near the southerly end of the lake from which the water is in danger of being polluted, but by the enforcement of the rules adopted recently by this Board (June 4, 1908) for the sanitary protection of this source, and by making such changes in existing structures and the construction of such sewers as may be necessary, the waters of the lake can be protected from danger of pollution without serious difficulty.

The Board approves the use of Lake Pleasant as a source of water supply for the Lake Pleasant Water Supply District.

NEWBURYPORT.

APRIL 2, 1908.

To the Board of Water Commissioners of the City of Newburyport, MR. CHARLES A. BLISS, *Chairman.*

GENTLEMEN: — The State Board of Health received from you on March 20, 1908, the following application for the approval of plans for an additional water supply for the city of Newburyport: —

The following is a general description of the proposed additional water supply for the city of Newburyport, which it is proposed to obtain from the Artichoke River.

A dam will be constructed across the river at a point near the Curzon Mill Road, so called. It is proposed to construct the dam of concrete and with the crest at such an elevation that the average high water (or tide) in the Merrimack River will be excluded, and, by placing tide-gates and stop-

planks on top, to prevent any extreme high water in the Merrimack from entering the Artichoke.

The intake and pumping station will be located at Storey Avenue, and the water pumped to a point on Ferry Road, from which it will flow by gravity on to the filter beds, which will be located at a point between the Ferry Road and the Jackman Ravine.

It is also proposed to construct a small open reservoir in the Jackman Ravine below the filter beds, to intercept or collect the filtered water. From the reservoir the water will flow through a 12-inch pipe to the present pumping station, the suction being so connected to the pumps that the water will be pumped directly into the distributing system of the city.

Detailed plans of the filter beds and reservoir are not yet completed, it being necessary to drive several test wells at the proposed site of the beds to determine the character of the material, depth to rock, etc., before completing them.

The accompanying plans show the location of the proposed dam, pumping station, filtration areas, etc., also details of the dam.

We would respectfully request the consent of your Board to the proposed plan as outlined above.

The application is accompanied by plans of the proposed works and a plan of the Artichoke River, with soundings and elevations of adjacent low lands. The plan presented provides in general for constructing a dam across the Artichoke River at Curzon Mill Road, so called, near its mouth, with its waste-way at grade 17 and with wing walls at grade 19. A sluice-way is provided through this dam which is fitted with double tide-gates, to prevent water from the Merrimack River from flowing back into the Artichoke River, the grade of the bottom of the sluice-way being 16. On the overflow of the dam it is proposed to erect a steel structure with its top at grade 18.5 and fitted with gates designed to allow the freshet flow to pass out into the Merrimack River but to prevent water passing back from that river at times of high water. You do not expect that high tides or freshets in the Merrimack River will exceed grade 18.5, the grade of the top of the overflow structure on the dam.

It is proposed to draw water from the Artichoke River at a pumping station to be located on the southerly side of the river, west of the State road and half a mile above the mouth of the stream. From this point the water is to be pumped through a 12-inch main to the filtration area to be located northeast of the Ferry Road, so called, in the neighborhood of the present water works. The details of the plan for filtering the water are not included in the plans now presented for consideration.

The Board has carefully examined the plans presented and concludes that they are suitable for the purpose, and consents to the taking of

Artichoke River for increasing the water supply of Newburyport, the water to be filtered before being supplied to the city.

The Board also approves the location of the dam, pumping station and force main shown on the plans presented.

The information available to the Board is not sufficient to show whether the proposed dam is high enough to keep out the highest freshets or tides in the Merrimack River. It is desirable that it be made high enough for that purpose.

The location of the force main in the neighborhood of the present works cannot be definitely decided until the plans of the proposed filters and reservoir have been determined upon, and it is understood that these are now in preparation and will be presented.

JUNE 4, 1908.

To the Board of Water Commissioners of the City of Newburyport, MR. CHARLES A. BLISS, *Chairman.*

GENTLEMEN: — The State Board of Health received from you on May 5, 1908, an application for its approval of the location of certain filters and a reservoir in Jackman Ravine for the purpose of filtering the water of the Artichoke River, in which you give the following outline of your proposed plans: —

It is proposed to take the water of the Artichoke River, in accordance with the plans already approved by you, and pump it to a point above the Jackman Spring, where during the summer months it will be discharged upon two open sand filter beds located as shown by the plan. These beds are to be prepared by the removal of the loam and subsoil from the surface and by levelling of the sand. During the winter months it is proposed to discharge the water of the Artichoke River into a system of 8-inch tile pipes laid about 3 feet beneath the surface of the ground upon the slopes of the ravines above Jackman Spring. No underdrains will be provided, but it is proposed to allow the water to find a natural outlet.

At a point a short distance below the present basin in Jackman Ravine it is proposed to construct a reservoir having a capacity of about 600,000 gallons, in which to collect the filtered water. In order that no water may escape, sheet piling will be driven to bed rock and the dam built above the piling. It is proposed to construct this basin so that it can be covered if the necessity should arise.

The quantity of water which it is expected to treat upon the proposed filter beds amounts to about 500,000 gallons per day at the present time, and all of this water will be pumped in a few hours, the filters and drain receiving no water during the remaining hours of the day.

The application is accompanied by a plan showing the location of the proposed works. Two open filter beds are shown upon this plan,

having areas, respectively, of 30,000 and 11,000 square feet, or an aggregate area of a little less than 1 acre, so that the proposed rate of filtration would be between 500,000 and 600,000 gallons per acre per day. The system of subdrains for use in the winter season is located outside of and about the filters, the aggregate length of the drains being about 4,700 feet. The information as to the depth to ground water and to ledge in the region about the proposed filters, obtained by sinking tubular wells, is also shown upon the plan.

The Board has caused the locality to be examined by its engineer and has considered the plan presented.

The soil in and about the Jackman Ravine, as shown by wells and test pits, is well adapted to the purification of water by intermittent filtration, and the proposed works should, in the opinion of the Board, be capable of purifying efficiently the water of the Artichoke River so that it would be of satisfactory quality for water-supply purposes.

It is impossible to determine beforehand whether the water collected in the proposed reservoir in Jackman Ravine will be affected by growths of organisms. The water of the present reservoir in the Jackman Ravine does not appear to be affected by such growths, and considering the circumstances it is probably best to build the reservoir without covering, and to make such provision as is practicable for covering it in the future if necessary, as proposed.

The location of the proposed reservoir appears to be suitable for the collection of the water from the filters. The elevation of the ledge east of the proposed reservoir has not been definitely determined, and it is desirable that further soundings be made in that direction, though the indications are that the ledge is high enough to prevent the escape of filtered water. The chief danger of the escape of filtered water appears to be in a direction west from the reservoir, where the elevation of the ledge is low, but it is likely that water escaping in that direction would be intercepted by the wells from which a part of the present supply is obtained and the use of which will be continued in the future.

The filtered water will flow, in part, in open channels into the proposed reservoir, and it will be very important to provide adequate means for preventing danger of its pollution.

The Board approves the plan presented for filtering the water of the Artichoke River and the location of the proposed works.

JULY 2, 1908.

To the Board of Water Commissioners of the City of Newburyport.

GENTLEMEN: — The State Board of Health has considered your application for approval of the use of water from wells in the Common Pasture as a temporary supply to meet an emergency caused by a

shortage of water in your usual sources of supply, and has caused a sample of the water from the wells to be analyzed.

The results of the analysis show no very material change in the character of this water since last year, when you were advised as to its quality.

It appears that the new supply now being introduced from the Artichoke River will not be available for several months, and in view of the circumstances the Board approves the use of water from the wells in the Common Pasture used last year to relieve the present emergency.

The use of water from wells in the Common Pasture as an emergency supply for the city of Newburyport is herein authorized under the provisions of chapter 25, section 35, of the Revised Laws, and by the terms of the statute cannot be continued for more than six months. The use of this water should be discontinued as soon as practicable.

NEWTON.

AUG. 6, 1908.

To Mr. IRVING T. FARNHAM, *City Engineer, Newton, Mass.*

DEAR SIR:—The State Board of Health received from you on Aug. 4, 1908, an application for its advice as to a plan for a further extension of the works near Charles River for the collection of ground water for the water supply for the city of Newton, accompanied by plans and information relative to the existing and proposed works.

The plan submitted provides for extending a conduit 30 inches in diameter from the connection of the present main and branch conduits near Kendrick Street, along the southerly side of Charles River, to the neighborhood of Hardy Street, a distance of about 3,600 feet. The conduit is to be built of concrete and is to be laid throughout its length with its invert at grade 81 above Newton city base, or about 10 feet below the ordinary level of the water in the river, the grade of the conduit being the same as the grade of the existing conduit west of Kendrick Street. In the trench with this conduit, and at somewhat lower level, a pipe is to be laid with which tubular wells will be connected and from which there are to be connections into the main conduit at frequent intervals. Each tubular well is to be provided with a separate gate by which its use can be discontinued if desired, and provision is to be made for shutting off groups of wells if necessary. For the greater part of its length the conduit will be located in a low ridge of upland above the ordinary level of high water in the river, and its distance from the river will range from 300 to 700 feet.

Numerous test wells have been driven in previous years in the lands controlled by the city of Newton along the Charles River, especially in

the region south of the river between Kendrick Street and the Dedham boundary, and observations of the height of water in these wells, carried on in the summer of 1905, have been submitted.

Recently numerous test wells have been driven along the line of the proposed conduit, and samples of water from several of these wells have been analyzed by the Board.

The Board has caused the locality to be examined by its engineer and has carefully examined the plans and the information presented therewith. Observations of the height of ground water in the neighborhood of the river east of Kendrick Street show that in a large part of the region in which the proposed conduit is to be constructed the water probably already finds its way, during the drier portion of the year, toward the existing conduit; but the ground water in most of this region is at present but little below the level of the river, and by the construction of the new conduit it will evidently be practicable to draw a much larger quantity of water from the storage in the ground and also to increase the filtration of water into the ground from the river.

The test wells driven along the line of the conduit during the present year show that strata of gravelly soil yielding water freely are found at no great distance below the surface throughout most of the length of the conduit, excepting in a length of about 800 feet nearest Kendrick Street, and analyses of samples of water from several of these wells indicate that water of good quality for all purposes of a public water supply can be obtained from the ground in this region.

The Board is of the opinion that the proposed plan of enlarging the system of water supply of the city of Newton by extending a conduit from Kendrick Street to the neighborhood of Hardy Street, with a system of tubular wells connected thereto, is an appropriate method of increasing the water supply of the city.

NORTH ADAMS.

DEC. 3, 1908.

To the Board of Health of the City of North Adams.

GENTLEMEN: — In response to your communication requesting a further examination by the Board of the water of the 2 deep tubular wells located near Ashland Street in the central part of the city of North Adams, and advice as to its quality, the Board has caused an examination of the wells and their surroundings to be made by one of its engineers and samples of the water to be analyzed.

The first sample analyzed during the present year was collected on October 16, just after the pumps had been started to supply this water to the city. This sample evidently does not represent the water of the

wells, and the results of that analysis being obviously anomalous must be rejected. The next samples were collected on October 26, ten days after the pumping had begun, one sample being collected from each of the wells, and on November 10 a fourth sample was collected, which represented a mixture of water from both wells.

During the period in which these samples were collected there has been a marked deterioration in the quality of the water. The analysis of the last sample shows that the water then entering the well had at some time been considerably polluted by sewage, though up to that time it was being quite thoroughly purified in its passage through the ground before entering the wells. The wells are located in the thickly populated portion of the city, and it is evident that much of the water which enters them percolates down from the surface in the immediate vicinity. Complaint has been made of the quality of the water, which is believed to have injured at times the health of those who use it, and its hardness is excessive.

In the opinion of the Board the wells are not suitable sources from which to take water for drinking. The water supply ordinarily used by the city, obtained from Broad Brook and Notch Brook, is naturally of good quality for water-supply purposes, but it is obvious that the quantity of water which these sources will furnish at their present development is insufficient for the requirements of the city in dry seasons, and unless the capacity of the works is enlarged a shortage is likely to be experienced more frequently in the future.

It is very important, in the opinion of the Board, that the city should provide for itself, as soon as practicable, an adequate supply of good water sufficient for its requirements at all times. There are various ways in which an additional supply of water can be obtained, and it is not unlikely that the best plan might be to take water from the ground at some suitable place near the city, but at a sufficient distance from populated districts to avoid danger of the pollution of the water therefrom. The Board recommends that investigations for an additional water supply for the city be made without delay, and that they include an investigation of the practicability of securing a good ground-water supply to replace the objectionable sources now in use.

The Board is prepared to assist the city of North Adams in making investigations for an additional water supply by making the necessary analyses of water, and will, upon application, examine any proposed sources of supply and advise the city as to any plan for increasing its water supply that it may wish to present.

NORTH ADAMS (WELLS).

DEC. 3, 1908.

To the Board of Health of the City of North Adams.

GENTLEMEN: — In response to your request for an examination of the water of a well at the factory of the Barber Leather Company, near Union Street in North Adams, and advice as to its quality, the Board has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water entering the well has at some time been considerably polluted but subsequently quite well purified in its passage through the ground, and in the condition in which it was found at the time the examination was made the water of this well was probably safe for drinking. The well is located in a thickly populated district, containing many possible sources of pollution, and there is danger that the water may deteriorate in quality at any time and become unsafe for use.

Under the circumstances the Board is unable to recommend the continued use of the water of this well for drinking, and when an adequate supply of good water has been provided by the city, the further use of water from this well for drinking should be prevented.

An examination has also been made of the water of a well at the Hotel Richmond, near State Street, the results showing that the water is badly polluted and unsafe for drinking. The Board would recommend that its use for that purpose be prevented.

NORTHBRIDGE (WELL AT ALMSHOUSE).

SEPT. 3, 1908.

To the Board of Selectmen of the Town of Northbridge, Mr. E. KENT SWIFT, *Chairman.*

GENTLEMEN: — In response to your request of August 7 for an examination of 2 wells from which you propose to take water for the supply of the town almshouse, and advice as to its quality, the Board has caused the wells and their surroundings to be examined and samples of their waters to be analyzed.

The water of the well used by the warden, and located close to the buildings, is very badly polluted, and the Board would recommend that the further use of this well be prevented.

The water of the well used by the inmates has at some time been considerably polluted but subsequently quite well purified in its passage through the ground before entering the well, and, in the condition shown by the recent analysis, the water is probably safe for drinking. It is understood that you propose to collect and remove all the sewage of

the almshouse to a point southeast of the buildings and quite remote from this well, and if this is done, and the neighboring vault removed at once, it is probable that the water of the inmates' well can safely be used for drinking.

You have also requested an examination of the water of a small pond north of the buildings and advice as to its use as a source of ice supply. The water of the pond contains an excessive quantity of organic matter, and there is an extensive growth of aquatic plants in its bottom, and in its present condition it would not be a suitable source of ice supply. If its depth should be increased to 3 feet or more, and the vegetable matter removed from the bottom, ice which might safely be used for domestic purposes could be obtained from it, provided only the clear ice free from foreign matter be used for such purposes. There is no objection to the use of ice from this source for cooling where it does not come in contact with food or drinking water.

NORTHFIELD (EAST NORTHFIELD).

JUNE 4, 1908.

To Mr. A. G. MOODY, *East Northfield, Mass.*

DEAR SIR: — In response to your verbal request for an examination of the water of Glen Spring, so called, in the valley of Louisiana Brook in East Northfield, and certain other springs in its neighborhood, the State Board of Health has caused the springs and their surroundings to be examined and samples of their waters to be analyzed.

The character of the water of Glen Spring has not changed since the previous examination was made, and its use for drinking may safely be continued.

Four other small springs in the valley of the brook near Glen Spring have been examined and their waters analyzed. One of these is located on the northerly side of the brook, and the other three on the southerly side. The spring on the northerly side does not appear to be exposed to danger of pollution, and if the spring shall be covered and danger of the entrance of surface water prevented, its water can safely be used for drinking. The springs on the southerly side of the brook all show evidences of pollution, and are evidently affected by drainage from buildings on the edge of the slope above the springs. In the opinion of the Board these springs are not safe sources from which to take water for drinking.

NORTH READING (TOWN WELL).

AUG. 6, 1908.

To Mr. FRANK W. CASE, *Road Commissioner, North Reading, Mass.*

DEAR SIR: — In response to your request for an examination of the water of the town well in North Reading Square, and advice as to its

quality, the Board has caused the well and its surroundings to be examined and samples of the water to be analyzed.

The results of the analyses show that at this time the water was clear, colorless and odorless, and contained but little organic matter. It was somewhat hard and there was some evidence of previous pollution, though the water had evidently been well purified in its subsequent passage through the ground before entering the well.

The most notable feature of the analyses was the presence of an excessive quantity of chlorine. An investigation as to the cause shows that it is probably due to the discharge of salt water from an ice-cream saloon upon the ground close to the well. It is understood that the ice-cream saloon has recently been removed from this locality, and it is evident from the analyses that the chlorine in the water is diminishing rapidly. It is not improbable that the quantity of chlorine present in the water was even higher before the first analysis was made, and that it was sufficient to be noticeable to the taste.

In the opinion of the Board the water in its present condition is probably safe for drinking.

North Reading (Well at Boston & Maine Railroad Cottage).

Aug. 6, 1908.

To Mr. W. D. Fitts, *North Reading, Mass.*

Dear Sir: — In response to your request of July 18, 1908, for an examination of the well at the Boston & Maine Railroad cottage, which, you state, is used as a general drinking place for the public, the Board has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water has been at some time considerably polluted and not thoroughly purified in its subsequent passage through the ground before entering the well, and that it contained at the time it was examined a very large number of bacteria, including those characteristic of sewage.

In the opinion of the Board the well is an unsafe source from which to take water for drinking or cooking.

North Reading (Well at Factory of J. B. McLane).

Aug. 6, 1908.

To Albert P. Norris, M.D., *State Inspector of Health, Cambridge, Mass.*

Dear Sir: — In response to your request of June 30, 1908, for an examination of the water at the factory of J. B. McLane in North Reading, and advice as to its quality, the Board has caused the well and its surroundings to be examined and samples of the water to be analyzed.

The results of the analyses show that the water was at this time clear, colorless and odorless, and contained but little organic matter and very few bacteria. There was evidence, however, that it had at some time been considerably polluted but subsequently well purified in its passage through the ground before entering the well.

The most remarkable feature of the analyses was the presence of an excessive quantity of chlorine, and investigation shows that it is probably due to salt water discharged upon the ground at an ice-cream saloon across the street. It is understood that this saloon has been removed, and the second analysis shows that the quantity of chlorine is diminishing rapidly.

The water of this well in its present state is probably safe for drinking.

PALMER.

SEPT. 3, 1908.

To the Board of Health of the Town of Palmer, Mr. F. N. CARPENTER, *Clerk.*

GENTLEMEN: — In response to your communication of Aug. 19, 1908, stating that you are receiving numerous complaints of the quality of the water supplied by the Palmer Water Company, and requesting an investigation and report upon the conditions found, the Board has caused the sources used by the Palmer Water Company to be examined by its engineer and has examined the results of analyses of samples of water collected therefrom.

The results of the examination show that the water is turbid and highly colored and that it contains a large quantity of organic matter, and during the summer has a disagreeable taste and odor. The height of the water in the main reservoir has recently been raised by an increase in the height of the dam or flashboards, but the area flowed has not been cleaned, and an extensive area of swamp at the upper end of the reservoir, covered with bushes, trees and organic matter of various kinds, has been flooded to a small depth by the water during the past summer. The present objectionable condition of the water is no doubt due largely to its contact with organic matter in this swamp.

The condition of the water of this reservoir was objectionable, however, at times before its level was raised, and it is unlikely that if the flashboards were removed and the height of water reduced to its original level satisfactory water would be obtained at all times from this source. An improvement in the quality of the water could doubtless be effected by cleaning the reservoir, and if the soil and organic matter should be removed from the swamp at the upper end, the water in the reservoir might be kept at the level of the present high-water mark without injury to its quality. It would be difficult, if not impracticable, however, to

clean the reservoir properly without first obtaining a water supply from some other source, and the only practicable plan of securing good water from the present sources of supply is probably to filter the water before supplying it to the town.

The quantity of water which the sources of supply of the Palmer Water Company are capable of yielding in a dry season is entirely inadequate for the requirements of the present village of Palmer, and unless an additional supply shall be provided a very serious shortage of water is likely to occur in the next dry season. It is not desirable, under the circumstances, to undertake extensive improvements in the present sources until a satisfactory additional supply has been selected, and if a supply of good water shall be secured from some other source it may be desirable to discontinue the use of the present sources, or to maintain the reservoirs only for use in emergencies.

A public supply of good water is very badly needed in other districts in the town of Palmer as well as in the main village, and the Board recommends that the town take such steps as may be necessary to secure the introduction of an adequate supply of good water, not only for the main village but for the other districts in the town requiring a public water supply.

SEPT. 3, 1908.

To the Palmer Water Company, Palmer, Mass.

GENTLEMEN: — In response to a request of the authorities of the town of Palmer for an examination of the sources of water supply of the Palmer Water Company, and information as to the quality of the water and the cause of its present objectionable condition, the Board has caused the sources of supply and their surroundings to be examined by its engineer, and has advised the board of health of the town as to the causes, in its opinion, of the objectionable condition of the water. A copy of this communication is enclosed herewith.

It is probably impracticable to improve materially the quality of the water supplied from your present sources without filtration, but the quantity of water which they are capable of furnishing in a dry season is inadequate for the requirements of the village, and the Board recommends that before deciding upon plans for improving the quality of the water you cause an investigation to be made with a view to obtaining an additional supply of water for the village from some suitable source. The Board advises that the investigation be made with the assistance of an engineer of experience in matters relating to water supply, and if you decide to make the investigation suggested the Board will assist you by making the necessary analyses of water and will give you further advice when you have the results of the investigation to present.

PALMER (WELL AT ALMSHOUSE).

AUG. 6, 1908.

To the Board of Overseers of the Poor, Palmer, Mass.

GENTLEMEN: — The attention of the State Board of Health has been called to the sources from which the almshouse in the town of Palmer is now supplied with water for drinking, and the Board has caused these sources and their surroundings to be examined and a sample of the water to be analyzed.

The sources in use are two springs, the water from which overflows into two small basins, from which it is forced by rams to the buildings. The basins from which the water is now drawn are so located that drainage from the highway and neighboring cultivated lands evidently finds its way into them at times of heavy rain, and the results of an analysis of a sample of water from one of the basins shows the presence of bacteria characteristic of sewage, and under the conditions the water cannot be considered safe for drinking. While the springs are located nearer the buildings than desirable, it is probable, in the opinion of the Board, that if they were covered, and protected thoroughly from the entrance of surface water, their waters would be of good quality and might safely be used for the supply of the almshouse.

PALMER (THORNDIKE MANUFACTURING COMPANY).

FEB. 6, 1908.

To the Thorndike Manufacturing Company, Thorndike, Mass.

GENTLEMEN: — The attention of the Board has been called to the sources from which water is supplied for drinking and other purposes in your factory buildings and to the tenement houses under the control of your company in the village of Thorndike, and the Board has recently caused these sources to be examined by one of its engineers and samples of their waters to be analyzed.

One of the sources of supply is a spring located in the yard of mill No. 2, from which water is supplied, under pressure, in tenements occupied by about 70 families. The results of an analysis of this water show that it is badly polluted and unsafe for drinking, and the Board recommends that its further use for that purpose be prevented.

A well located near this spring is used as a source of drinking water supply in the mill, water being pumped from the well by means of a hand pump and carried in pails to different parts of the mill. The analysis of this water indicates that at the present time it is safe for drinking. There are possible sources of pollution at no great distance, however, and, while the use of this well as a source of water supply

continues, the water should be analyzed from time to time in order that if deterioration occurs its further use may be discontinued.

At mill No. 1 the drinking water is drawn from a well located beneath the floor of the weaving room, and the results of an analysis of a sample of the water show that it has been very badly polluted, though subsequently quite well purified before entering the well. While this water may not be injurious for drinking at present, the conditions are such that this well cannot be regarded as a safe source of water supply, and its use should be discontinued as soon as a supply of water of good quality can be introduced.

Water from the Ware River is supplied in both of the mills for washing and other purposes. The Ware River is polluted by large quantities of sewage discharged into the stream at Ware and other places above Thorndike, and the water supplied through the faucets in your factory from that stream is likely to injure seriously the health of those who use it for drinking. In many places in mill No. 2 the sinks are provided with two faucets, one supplying spring water and the other supplying river water, and no means are provided by which the operatives or others may distinguish the two waters. The water of the Ware River should not be supplied at any point in the mills or tenements where it will be available for drinking.

The Board has also caused examinations to be made of the waters of several other wells and springs located on property of the company and used by a number of families in the village as sources of water supply, all of which were found to be polluted by sewage in a greater or less degree.

A well at 21 Church Street, said to be used by 14 families, shows evidence of considerable pollution, but, in the condition in which it was found at the time the examination was made, the water of this well is probably safe for drinking.

The water of a well at 13 Pine Street was of very similar character to the well at Church Street above described. While these waters are probably, at the present time, safe for drinking, there are sources of pollution at no great distance, and the quality of the water is likely to deteriorate with continued use.

A well located at the northerly end of Four-row Street was found to be very badly polluted, and in the opinion of the Board its further use should be prevented.

A well located near the railroad station is the most polluted of all, and the further use of that well, also, should be prevented.

A supply of good drinking water should be provided for the mills and tenement houses in this village as soon as possible. In the mean

time all persons to whom the waters of the objectionable wells and springs are supplied should be notified that they are unsafe for drinking purposes unless they have been boiled for at least fifteen minutes, and the boiled water should be handled with care and danger of its pollution after boiling avoided.

Notices should be maintained on all the faucets through which river water is supplied giving warning of the danger of the use of the water for drinking and stating that it is poison.

PALMER (BOSTON DUCK COMPANY).

Nov. 5, 1908.

To the Boston Duck Company, Bondsville, Mass., MR. E. G. CHILDS, *Agent.*

GENTLEMEN: — The State Board of Health received from you, through your engineer, on Aug. 27, 1908, an application for advice with reference to taking water from wells in the valley of Jabish Brook a little more than a quarter of a mile from the Swift River, for the supply of the factories and dwelling houses belonging to the company and situated in the village of Bondsville, for drinking and domestic purposes, and in response to this application has caused the locality to be examined by its engineer and samples of water from test wells there to be analyzed.

The results of the examination indicate that water of good quality can be obtained from the ground where the tests have been made, and the wells penetrated a porous stratum from which water could be obtained quite freely. In the opinion of the Board the indications furnished by the investigations thus far made are favorable for obtaining a supply of good water in this locality sufficient for all reasonable requirements in your mills and tenement houses.

PALMER (WELL IN BONDSVILLE).

JUNE 4, 1908.

To the Board of Health of the Town of Palmer.

GENTLEMEN: — The attention of the State Board of Health having been called to the well used as a source of water supply by the school in Bondsville, the Board has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water is very badly polluted and unsafe for drinking, and the Board recommends that the possibility of its further use for that purpose be prevented.

PEPPERELL.

JAN. 2, 1908.

To the Water Committee of the Town of Pepperell, Messrs. ARTHUR P. WRIGHT and E. L. TARBELL.

GENTLEMEN: — The State Board of Health received from you on Aug. 13, 1907, an application for advice with reference to a proposed water supply for Pepperell, to be taken from the ground in the valley of Nissitissit River, or some other source in that neighborhood, and subsequently test wells were driven in the valley of Gulf Brook, a short distance above its junction with Nissitissit River, and samples of water from several of these wells were analyzed. The results of the analyses indicating that water of good quality might be obtained from the ground in this region, additional wells were put in and a test made by pumping continuously from a group of 16 wells in this locality from November 14 to November 21, inclusive, at a rate of about 350,000 gallons per day.

The Board has caused the locality to be examined by its engineer and has considered the information presented and the results of analyses of samples of water collected from the wells while the pumping was in progress.

The results of the analyses show that the water is of excellent quality for all the purposes of a public water supply.

The quantity of water pumped during the test was considerably in excess of the quantity likely to be required by the town of Pepperell, and while the test was made in a period when the rainfall was unusually large, the indications are that a sufficient quantity of water for the requirements of Pepperell can be obtained from the ground in the locality in which the test was made.

In the opinion of the Board the source proposed is an appropriate one from which to take water for the supply of the town of Pepperell. A public water supply is, in the opinion of the Board, greatly needed in this town for the protection of the public health, analyses of the waters of many wells in various parts of the villages having shown in practically all cases that these sources are very badly polluted.

PITTSFIELD.

NOV. 12, 1908.

To the Board of Public Works of the City of Pittsfield.

GENTLEMEN: — The State Board of Health received from you on Oct. 20, 1908, an application requesting approval by the Board of the taking of water from Onota Lake as a temporary water supply for the city of Pittsfield, and in response to this application has caused the lake

and its surroundings to be examined by one of its engineers and has examined the results of analyses of samples of its waters.

Lake Onota is separated into two divisions connected by a narrow channel known as the Narrows. The southerly division, having the larger area and a greater capacity, is quite deep, with steep, clean shores and apparently a gravelly bottom. The water is of good quality, and while there are a few dwelling houses near the outer limits of the watershed, this portion of the lake is not at present exposed to serious danger of pollution.

The northerly division of the lake differs greatly in all respects from the southerly division. It was formed chiefly artificially, when the level of the lake was raised for manufacturing purposes, and at the present time, the water having been drawn down during the past summer, the bottom is exposed over most of its area. The watershed of this section of the lake is very much larger than that of the southerly section and there are many houses about its shores and near the streams which enter it. Analyses of the water show usually the presence of a larger quantity of organic matter than is found in the southerly section of the lake.

It appears to be practicable, by providing temporary pumping works and laying a force main a little over half a mile in length, to pump water from the southern part of the lake into one of the distributing mains of the city, and enough water can probably be introduced in this way for the supply of the city in addition to the quantity obtainable from the present sources.

It is not desirable to take water from the northerly portion of the lake.

With the suggestions contained herein, the Board approves the taking of water from Onota Lake as a temporary water supply for the city of Pittsfield, under the provisions of chapter 25, section 35, of the Revised Laws.

DEC. 3, 1908.

To the Board of Public Works of the City of Pittsfield.

GENTLEMEN: — The State Board of Health received from you on Nov. 21, 1908, the following application for its approval of the taking by the city of Pittsfield of the waters of Roaring Brook as a temporary water supply for the city: —

By reason of the inadequate supply of water available from the present water system of the city of Pittsfield, it is necessary to temporarily take the waters of Roaring Brook and conduct the same into Mill Brook, and thence into the present water system.

The board of public works of the city of Pittsfield plan to take said waters at a point in the brook about 500 feet below the place where said

brook crosses the highway leading from New Lenox to the Whitney house on October Mountain, so called.

Proceedings are to be had for such temporary taking under the provisions of chapter 25 of the Revised Laws, or under the provisions of chapter 514 of the Acts of 1907, and the approval of your Honorable Board is hereby requested in accordance with the provisions of law.

The water of Roaring Brook is highly colored and contains much vegetable matter, and in consequence the stream is not a desirable source of water supply. Its watershed is, however, practically uninhabited, and the use of this brook temporarily is not likely to be injurious to the health of the city. The source is the best one available from which to obtain an additional supply of water by gravity in the present emergency, and the Board approves its use as a temporary water supply for the city of Pittsfield under the provisions of chapter 25, section 35, of the Revised Laws.

It is no doubt practicable to obtain water of good quality from the watershed of Roaring Brook for the permanent use of the city of Pittsfield, but until definite plans for developing a supply of good water from this source have been prepared, it is not desirable, in the opinion of the Board, that action be taken under the provisions of chapter 514 of the Acts of the year 1907.

Plymouth (Elder Brewster Spring).

June 4, 1908.

To the Board of Selectmen of the Town of Plymouth.

Gentlemen: — In response to your request of May 18, 1908, for an examination of the water of Pilgrim or Elder Brewster Spring, so called, and advice as to its quality, the State Board of Health has caused a further examination of the surroundings of the spring to be made and a sample of the water to be analyzed.

It appears that a new street has been constructed over the site of the spring, which is now covered by a depth of 15 feet of gravel. The water has, however, been piped through a cast-iron pipe to the side of the street, where it now discharges into a barrel sunk into the ground, from which it is proposed to pump the water to a drinking fountain.

The results of the analysis of the water show no very material change since the previous analysis was made, and in the opinion of the Board the water may still be considered safe for drinking. It will be necessary, however, to make sure that the water cannot be polluted after leaving the pipe from which it is now discharged.

ROWLEY (WELL OF W. C. FOSTER'S SONS).

APRIL 2, 1908.

To Mr. GEORGE B. PRIME, *Clerk, Board of Health, Rowley, Mass.*

DEAR SIR: — In response to your request for an examination of the water used at the shoe factory of William C. Foster's Sons, and of the water of the Paradise Spring Water Company, sold in Rowley and other towns for drinking, the Board has caused these sources of supply to be examined and samples of their waters to be analyzed.

The spring of the Paradise Spring Water Company is located in an uninhabited region and the water is naturally of good quality for drinking. Before using it for the purpose now proposed the spring should be carefully walled up and covered to exclude surface water and prevent its pollution thereby, and suitable means for drawing the water in such a manner as to avoid endangering its quality should be provided.

With the changes suggested properly carried out the water of this spring may, in the opinion of the Board, safely be used for drinking.

The well from which it is proposed to take a supply for the William C. Foster's Sons shoe factory is located in a region containing a considerable number of possible sources of pollution at no great distance from the well, and the results of an analysis show that the water contained a larger amount of organic matter than is found in good drinking water. While the water of this well may not in its present state be unsafe for drinking purposes, it is not a desirable source of drinking water under the circumstances, and the Board cannot recommend its continued use for that purpose.

SANDWICH (BATTERY A, M. V. M.).

JULY 17, 1908.

To GEORGE OSGOOD, M.D., *Captain and Assistant Surgeon, Hospital Corps, M.V.M., South Armory, Irvington Street, Boston, Mass.*

DEAR SIR: — In response to your request of July 6, 1908, for an examination of Peter's Pond, Wakeby Pond and of the northernmost of the three Cotuit Ponds in the town of Sandwich, and advice as to their fitness for drinking, the Board has caused an examination of the ponds and their surroundings to be made and samples of their waters to be analyzed.

The waters of all of the ponds are naturally of good quality, and while there is a small population near the Wakeby Pond and near the most northerly of the Cotuit Ponds, it is probable that the waters of all of the ponds are, under present conditions, safe for drinking. The water of Peter's Pond is the best of the three. With a camp of soldiers

near its shores, however, it will be essential to guard the purity of the water carefully.

Water for drinking and cooking can probably be obtained without difficulty in this region from tubular wells located a few feet back from the shores of the ponds. Such wells are not very expensive, and if located at points unaffected by local pollution would furnish water of excellent quality, and the use of the pond waters for those purposes could then be avoided.

SHELBURNE (SHELBURNE FALLS FIRE DISTRICT).

DEC. 3, 1908.

To the Committee on Water Supply, Shelburne Falls, Mass.

GENTLEMEN: — The State Board of Health received from you on Nov. 23, 1908, the following application for advice as to a proposed system of water supply for Shelburne Falls: —

> Referring to your letter of July 7, 1904, regarding the Clark Brook as a source of supply for the Shelburne Falls Fire District, we are now considering not only this brook but the Avery Brook in Charlemont, the Fox Brook in Colrain and the Deerfield River as a pump supply for fire purposes only.
>
> It is necessary for us to know if all these proposed sources would meet the approval of your board, and what precautions in respect to certain buildings would be necessary, before making our report. A survey covering all these sources is now being made.
>
> As the law requires that publication of a petition shall be first made by the 9th of December, we hereby request that you make an examination of these several propositions next week, if possible, in order that we may have time to frame our petition and properly publish same.

In response to this application the Board has caused the various sources mentioned, and others in the neighborhood of Shelburne Falls, to be examined by one of its engineers and samples of their waters to be analyzed, and has considered the results of the investigations relative to a water supply for the village of Shelburne Falls made in previous years.

The flow of Clark Brook appears to have been very well maintained during the past dry season, and it is probable that the natural flow of that stream would furnish enough water for the requirements of Shelburne Falls without storage. The same is probably true of Avery Brook, but the dry weather flow of Fox Brook appears to be quite small, and the indications are that a storage reservoir would be necessary in order to obtain a sufficient quantity of water from that source for the supply of the village.

The cost of works for obtaining a water supply for Shelburne Falls would probably be greatest in the case of Avery Brook or Fox Brook and least if the water were taken from Clark Brook.

The waters of all of these brooks, as shown by the results of analyses, are naturally of good quality for water-supply purposes, but all three streams are exposed to pollution from the population within their watersheds, and none of them can be regarded as a safe source of water supply under present conditions. The population is greatest within the watershed of Avery Brook, which includes part of the village of Heath, and is probably least in the valley of Fox Brook, where there are few if any permanent dwelling houses, but this stream is exposed to danger of pollution from lumbering operations carried on within its watershed.

It is probable that the watershed of Clark Brook could be protected from pollution at reasonable expense, but it would be necessary, if that source is to be used, that several of the groups of farm buildings within the watershed be acquired by the village, in order to insure adequate protection from danger of pollution of the water.

The water of Deerfield River is considerably polluted by the villages along the main stream and its tributaries, and the source would be a very unsafe one from which to take water for domestic purposes. It is not desirable, in the opinion of the Board, to take a water supply for fire purposes from the Deerfield River, since where water is introduced for such a purpose in a village having no general public water supply it is likely after a time to be used to a greater or less extent for drinking.

There is another plan by which an adequate supply of good water for Shelburne Falls might be obtained at a very reasonable cost, and that is by taking water from the ground at some point not far from the village. A general examination of the region indicates that conditions favorable for obtaining ground water, so far as can be judged from surface indications, are found at several places in the valley of the river or its tributaries above the town, and in the opinion of the Board it is very important that, before a source of water supply is definitely selected, tests be made to determine the practicability of obtaining a ground-water supply in the more favorable localities within reasonable distance of the village; since, if a sufficient quantity of ground water of good quality can be obtained in one of the more favorable localities, it is probable that a supply obtained in that way would be more satisfactory than from any of the other available sources.

The Board recommends that the investigations be made under the direction of an engineer of experience in the selection and development of ground-water supplies, and the Board will assist by making the neces-

sary analyses of water, and will give you further advice when you have the results of further investigations to present.

In making application to the Legislature for authority to introduce a supply of water into Shelburne Falls, request should be made for the right to take water from the ground in the valley of the Deerfield River or its tributaries in Shelburne or Buckland.

SHERBORN (REFORMATORY PRISON FOR WOMEN).

SEPT. 14, 1908.

To the Board of Prison Commissioners, MR. FREDERICK G. PETTIGROVE, *Chairman*.

GENTLEMEN: — In response to your request for an examination of Waushakum Pond, from which the water supply of the Reformatory Prison for Women is taken, and advice as to its condition, the Board has caused the pond and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water has at times considerable color and that it contains a larger quantity of organic matter than is found in good pond waters, the color and organic matter probably being derived from the contact of the water with vegetable matter in the bottom of the pond and in the swamps about it.

Compared with former examinations there is evidence of increasing pollution, due, no doubt, to an increase in the population on the watershed of the pond. An examination of the watershed shows that the population within its limits is large, amounting probably to about 450, or 375 persons per square mile, but 30 of the dwelling houses are said to be connected with the sewerage system of the town of Framingham, so that the sewage is removed from the watershed, leaving a population of about 270, or 225 persons per square mile of watershed, unconnected with the sewers.

The pond is evidently used to a considerable and increasing extent as a place of resort in summer, and there is much boating upon it in that season. It is said also that large quantities of ice are cut from it each year, involving the presence of a considerable number of persons upon and about the pond in winter.

In view of these circumstances there is much danger that the water may become polluted at any time in such a way as to injure the health of those to whom it is supplied for drinking, and under the circumstances the Board recommends that a new source of supply be secured for this institution, and that the further use of water taken directly from Waushakum Pond be discontinued.

A supply of water can no doubt be obtained from the works of the

town of Framingham at a reasonable rate, and there will be no serious difficulty in obtaining an adequate supply from that source. If, however, it is preferred to maintain independent works for the water supply of this institution, it is possible that an adequate supply of good water can be obtained from the ground at some place in the immediate neighborhood. If you should decide to make investigations with a view to obtaining an independent supply of ground water, the Board recommends that you secure the assistance of an engineer of experience in such matters to advise you as to the investigations, and the Board will assist you by making the necessary analyses of water and will give you further advice when the results of the investigations are available.

Somerset (Wells).

Nov. 5, 1908.

To the Board of Health of the Town of Somerset.

Gentlemen: — In response to your request for an examination of a well situated on the Luther lot, so called, on Maple Street, about 250 feet west of High Street, and advice as to the quality of the water, the State Board of Health has caused the well and its surroundings to be examined and a sample of the water to be analyzed.

The results of the analysis show that the water has been at some time considerably polluted and contains a larger quantity of organic matter than is found in good well waters.

An examination of the water of a well at the house of Dr. Morrill on Clark Street, near by, shows that the water of that source also has been considerably polluted though subsequently quite well purified in its passage through the ground before entering the well.

While in their present condition the waters of these wells may not be unsafe for drinking, there are sources of contamination at no great distance from each of the wells, and the Board cannot recommend their use as sources of drinking water.

As a result of an examination of samples of water from many other wells in the village of Somerset, the State Board of Health, in a communication dated Nov. 7, 1907, called your attention to the importance of providing a public water supply of good quality for the use of this village. Such a supply of water is necessary for the adequate protection of the public health in the densely populated parts of the town of Somerset, and the Board again urges that this question be given immediate consideration by the town.

Somerset (Spring).

Nov. 5, 1908.

To Mr. A. H. Hood, *Fall River, Mass.*

Dear Sir: — In response to your request the State Board of Health has caused an examination to be made of a spring which supplies a public drinking fountain on the State highway, and of a well near the corner of County and South streets, in the town of Somerset, and samples of their waters to be analyzed.

The results of the analyses show that the water of the spring from which the supply of the drinking fountain is derived has at some time been polluted but subsequently quite well purified in its passage through the ground before entering the spring. The water contained, however, at the time of the examination on October 7, a larger number of bacteria than is found in good spring waters, including those characteristic of sewage.

The water of the well on County Street contains a somewhat greater quantity of organic matter than is found in good well waters, and the number and kinds of bacteria present are similar to those found in the water supplied to the drinking fountain.

In the opinion of the Board neither source can be regarded as a safe one from which to take water for drinking.

Southbridge.

March 5, 1908.

To the Southbridge Water Company, Southbridge, Mass.

Gentlemen: — The State Board of Health received from you on Feb. 3, 1908, through your engineer, an application for advice with reference to a proposed system of filtration for the water supply of Southbridge, in which your proposed plans are outlined as follows: —

It is proposed to construct 2 sand filter beds having a combined area of .26 of an acre, as shown on the plan. Water from reservoir No. 4 will be discharged intermittently upon these filters, the water being thoroughly aerated as it is discharged on the sand. The water will again be aerated after filtration. It is proposed to operate the filters only during the summer and fall, when the water is the most objectionable, so that it will not be necessary to cover them.

No records are kept of the quantity of water used in the town, but it is probably in the vicinity of 1,000,000 gallons per day during the summer, and when filtering this quantity the rate of filtration will be about 3,900,000 gallons per acre per day.

It is not proposed to filter the water of reservoir No. 3, which is situated just below reservoir No. 4, since it will not be necessary to use the water of this reservoir, except possibly at the end of a very dry season.

The application is accompanied by a plan of the proposed filters, showing their location and general method of construction. The filters are to be located below reservoir No. 4 and about 200 feet from reservoir No. 3. The elevation of the surfaces of the filters is to be 15 feet below the level of high water in reservoir No. 4, and the surface of the water in the basin in which the effluent from the filters is to be collected will be about 5 feet above the level of high water in reservoir No. 3.

The Board has considered the application and the plans submitted therewith and has examined the information available as to the character of reservoir No. 4 and its watershed, and the results of analyses of samples of the waters of Hatchet Brook and the reservoirs collected at various times.

The water of Hatchet Brook, collected at a point above the reservoirs, is low in color and contains but little organic matter, and is of good quality for water-supply purposes; and since the watershed contains but one or two dwelling houses, the water is not exposed to serious danger of pollution.

Analyses of the water of reservoir No. 3, constructed on this brook about twelve years ago, show that soon after it was first filled the water was highly colored and contained an excessive quantity of organic matter, due no doubt largely to the soil and organic matter which were allowed to remain in the bottom of the reservoir. The quality of the water gradually improved and became less objectionable until the construction of reservoir No. 4, a short distance above.

At the time of the construction of reservoir No. 4 the Board advised that that reservoir be prepared for the storage of water by the removal of the soil and organic matter from the area to be flowed, and that provision be made for taking water from the stream above the reservoir whenever it was found desirable to do so. These precautions were not observed, and the water of this reservoir, as shown by the analyses during the past year, has been characterized by a high color and the presence of a very large quantity of organic matter, making it very objectionable for drinking and other uses. Moreover, the water of this reservoir has had a very unfavorable effect on the quality of the water of reservoir No. 3, through which it finds its outlet.

It would be impracticable now to clean the bottom of reservoir No. 4, and under the existing conditions the best plan for improving the water supply of Southbridge is to filter the water through sand.

The plan now presented provides for the construction of open filters which can be used during most of the year, and, with slight changes, during part of the winter also. It is probable, in the opinion of the Board, that with the changes referred to the filters now proposed would

remove objectionable tastes and odors from the water at nearly all times; and while it is impossible to tell whether they would be capable of removing all odor from the water when the quantity of organic matter present is highest, in the late summer and early fall, they would no doubt effect a very decided improvement in quality.

Under the proposed plan the use of reservoir No. 3 would be discontinued, though this source would still be available and might be used in emergencies by pumping the water to the proposed filters. The indications are that the water of reservoir No. 3 will contain much less organic matter in the summer season than the water of reservoir No. 4, and it is probable that if provision were made for using water from reservoir No. 3 at times when the water of reservoir No. 4 is most seriously affected by organic matter it would be possible, under the proposed plan, to obtain satisfactory water at all times.

The consumption of water in Southbridge is unknown, but, so far as the information available to the Board indicates, it is much greater than is necessary, and by restricting unnecessary use and waste the quantity of water required for the supply of the town could probably be reduced very materially below the amount which now appears to be used. If the consumption of water is at the rate of 1,000,000 gallons per day, as has been estimated, the rate of filtration through the proposed filters would be 3,900,000 gallons per acre per day, and while one filter was being scraped the rate of the other filter might be twice or nearly twice as great as this.

Under the circumstances, unless some material reduction can be made in the consumption of water it would be better, in the opinion of the Board, to provide a larger area of filters than is now proposed, and by providing an area 50 per cent. larger, or about .4 of an acre, the rate need not be allowed to exceed the maximum rate which has thus far been found to be practicable in the purification of such waters, — that is, about 5,000,000 gallons per acre per day.

With the modifications suggested the Board is of the opinion that the plan of filtration proposed would make it practicable to supply satisfactory water to Southbridge at nearly all times.

SPRINGFIELD.

MARCH 5, 1908.

To the Board of Water Commissioners of the City of Springfield.

GENTLEMEN: — The State Board of Health received from you on Jan. 24, 1908, the following communication submitting plans of a proposed system of filtration for the water of the Little River supply of the city of Springfield: —

I am sending you by Boston-Springfield Despatch to-day one set of seventeen blueprints, together with one white print, colored. These seventeen blueprints bear our office numbers 636-14 to 642-14 inclusive, while the white print, which is a duplicate of one of the blueprints, except for the coloring, is not numbered. These plans are for a sedimentation and storage basin and for filters in connection with the Little River water supply for the city of Springfield, Mass., as required by section 2 of chapter 317 of the Acts of 1906.

These plans are hereby submitted to the State Board of Health for its approval, in accordance with section 5 of the above act.

Subsequently, on February 4 and 5, a plan of the proposed sedimentation basin and specifications of the proposed filters were received, showing the size and character of the settling basin and the character of the materials to be used in the construction of the filters, and on February 14 further information was submitted in response to a request of the Board relating to the proposed rate of operation of the filters.

The Board has examined the plans presented and the information available as to the character of the water of Little River and the watershed from which its water is derived. The watershed is very sparsely inhabited, and under present conditions the water can, by proper inspection, be protected from serious danger of pollution. The water is naturally of good quality, but is at times quite highly colored and after heavy rains is somewhat turbid.

In order to obtain a sufficient quantity of water from Little River for the supply of the city of Springfield in the drier portion of the year it will be necessary to construct a storage reservoir within the watershed, and plans already approved by this Board provide for the construction of one such reservoir on one of the branches of the stream, but details of this reservoir have not yet been presented. The water from this reservoir will flow for a distance of several miles in the channel of the stream and through the tunnel before reaching the filters. Other storage reservoirs are likely to be constructed within the watershed in the future, including a large one near the point at which the water is to be diverted.

The plans now submitted provide for the construction of a sedimentation basin, having a capacity of 40,000,000 gallons, and 6 covered sand filters, having an aggregate area of about 3.1 acres, the location of which has already been approved. The sedimentation basin is to be formed by constructing a dam in a small valley, and will have a natural drainage area of about 37 acres. If the area to be flowed is properly cleaned and the watershed kept free from pollution, this basin will be satisfactory for the purpose.

The sand to be used in the proposed filter, according to the specifications, is to have an effective size of .25 to .35 of a millimeter and a uniformity coefficient not exceeding 3. While under ordinary conditions, as already stated, pollution of the water can be prevented by proper inspection, it will be necessary at times to introduce large numbers of laborers into the watershed of Little River for the construction of reservoirs and making necessary improvements, and under such conditions the prevention of the pollution of the water will be more difficult, and the filters should be so constructed that they can be relied upon to prevent the effect of possible pollution. In the opinion of the Board it is desirable that the effective size of the sand be less than .35 of a millimeter, and the Board would recommend that the specifications be modified so that the effective size of the sand shall be between .24 and .30 of a millimeter.

The amount of the present consumption of water in Springfield is not definitely known, but it is estimated to be about 9,000,000 gallons per day, so that the rate of filtration will be about 2,900,000 gallons per acre per day when all the filters are in use and 3,460,000 gallons per acre per day when one of them is out of use for cleaning or repairs. While no experiments on the filtration of this water are available, the latter rate would probably be efficient in preventing the effect of possible pollution during much of the year, especially in the season when work is likely to be carried on in the watershed above, and, coupled with a careful inspection of the watershed of the stream for the prevention of danger of pollution, the Board is of the opinion that the area of filters proposed is sufficient to establish in the beginning. As the consumption of water increases higher rates will become necessary, but it will be practicable, before it becomes necessary to increase the rate materially, to determine the probable efficiency of various rates in the filtration of this water, and to make such further provision for the satisfactory protection or purification of the water as may be necessary.

With the change in the size of sand herein suggested, the Board approves the plan presented.

The Board would recommend that you secure rules and regulations for the protection of the water of Little River and provide for their efficient enforcement as soon as the use of this water is begun.

The high color by which the water of Little River is frequently affected is due to the contact of the water with organic matter in swamps. It will not be reduced materially by filtration, but can be greatly improved by draining swamps on the watershed, which, it is understood, is a part of your plan for developing a water supply for the city of Springfield from Little River.

Nov. 5, 1908.

To the Board of Water Commissioners of the City of Springfield.

Gentlemen: — The State Board of Health received from you on Sept. 29, 1908, through your chief engineer, the following application for the approval of the construction of a dam and reservoir on Borden Brook, at the boundary line between the towns of Blandford and Granville, shown upon a plan filed therewith: —

Under the authority granted the city of Springfield by chapter 317 of the Acts of 1906, entitled "An Act to authorize the city of Springfield to increase its water supply," the board of water commissioners of Springfield propose to construct a dam and reservoir on Borden Brook.

A report has been made by Mr. Allen Hazen, our consulting engineer, on this proposition, which report, together with the plan accompanying the same, is made a part of this communication.

Under section 5 of the above-mentioned act the approval of your Board is requested for the plans therein outlined.

The application and plan are accompanied by a report of your consulting engineer containing a description of the proposed scheme and recommendations relative thereto.

The dam is to be located in a narrow valley about 600 feet below the junction of Alder Brook with Borden Brook, at the lower end of an extensive area of quite level and mostly cleared land, surrounded by hills with steep slopes. The estimated area of the reservoir is 213 acres at high-water mark, the total storage capacity 2,478,000,000 gallons, the maximum depth about 60 feet and the average depth 35.7 feet. It appears that the drainage area has been found by surveys to be 7.95 square miles, which is considerably in excess of that indicated on the State map.

The reservoir site is to be cleaned by cutting all trees and bushes, removing the buildings, fences and perishable material and burning the bottom over immediately before flooding. It is also proposed to remove all stumps and roots which might become objectionable in appearance between contours 3 feet above and 12 feet below the flow line.

The water of this reservoir will flow through the channel of Borden Brook to the intake reservoir, a distance of about 6 miles, in which the fall of the stream is about 500 feet. From the intake reservoir it will be diverted to the filters, and after filtration will pass to the distributing reservoir and thence to the city.

The Board has examined the locality and has considered the plans and report submitted.

The site of the proposed reservoir is an excellent one for the purpose, and while it is located near the head waters of Little River, where the watershed is only about one-sixth of the entire watershed available to the city, its storage capacity is such that by its construction the yield of the stream will be made sufficient for all reasonable requirements of the city for many years in the future. The water drawn from this reservoir will flow for several miles in the steep and rocky bed of Borden Brook, mingling with the waters of streams from other parts of the watershed, and will subsequently be filtered before being delivered to the city. Under the circumstances it is not necessary, in the opinion of the Board, to prepare the reservoir very thoroughly for the storage of the water. The Board approves the plan presented.

Sterling.

Dec. 3, 1908.

To the Water Supply Committee of the Town of Sterling, Messrs. W. R. Mitchell, George F. Buttrick, Ralph H. Hosmer.

Gentlemen: — The State Board of Health has considered your application for advice as to taking water for the supply of the village of Sterling either from the head waters of Lydes Brook, a tributary of Waushaccum Pond, or from Smith's Spring, a tributary of Wekepeke Brook, and has caused the sources indicated to be examined by one of its engineers and samples of their waters to be analyzed.

The natural flow of Lydes Brook above the level at which water could be supplied to the village by gravity, as measured during the recent dry period, would not be sufficient for the purpose after water had come into general use, but by constructing a reservoir of considerable size on that stream, as proposed, the yield could doubtless be made sufficient for all the requirements of the village for several years. The analysis of the water of the brook shows, however, considerable evidence of pollution, due no doubt to drainage from the groups of farm buildings within the watershed, and it would be very difficult, if not impracticable, to protect the purity of the water adequately unless at a large expense, and in the opinion of the Board the source is not a desirable one from which to take water for the supply of the village.

Smith's Spring, so called, a tributary of Wekepeke Brook, has apparently a smaller watershed than Lydes Brook above the proposed location of the reservoir. The natural flow from the spring as measured during the past dry weather was not sufficient for the supply of the village, and it would be impracticable to construct a suitable reservoir on this stream of such size as would make it practicable to obtain from it a sufficient quantity of water for the supply of the village at all times. The water

of the spring is evidently of good quality, but under the circumstances the Board cannot recommend the selection of the spring as a source of water supply for Sterling.

The conditions in the valley of Smith's Spring and of the brook below appear to be favorable for obtaining water freely from the ground by means of wells or other suitable works for collecting ground water. It is also possible that water can be obtained from the ground in sufficient quantities for the requirements of the village in the valley of Lydes Brook west of and not far from the village, and the Board recommends that you make tests by means of tubular wells in the localities indicated, to determine the practicability and probable cost of obtaining a supply of good water sufficient for the village from the ground in either of the localities indicated. In making further investigations the Board recommends that you secure the assistance of an engineer of experience in matters relating to ground-water supplies, and the Board will assist you by making the necessary analyses of water, and will give you further advice when you have the results of further investigations to present.

WAKEFIELD (HEYWOOD BROTHERS & WAKEFIELD COMPANY).

JUNE 4, 1908.

To Messrs. HEYWOOD BROTHERS & WAKEFIELD COMPANY, *Wakefield, Mass.*

GENTLEMEN: — In response to your request for an examination of the water of a well used for drinking at your factory in Wakefield, and advice as to its quality, the State Board of Health has caused the well and its surroundings to be examined and samples of the water to be analyzed.

There are numerous sources of pollution about the well, and the results of the analyses show that the water is badly polluted. The Board recommends that the further use of water from this well for drinking be prevented.

WARE (PINE GROVE MINERAL SPRING).

JUNE 4, 1908.

To Mr. U. G. PAGE, *236 Day Building, Worcester, Mass.*

DEAR SIR: — In response to your request for a further examination of the Pine Grove Mineral Spring, so called, and advice as to its quality, the State Board of Health has caused a further examination of the water to be made and finds that there has been a marked improvement in its quality. In the opinion of the Board the water at the present time is safe for drinking.

WAREHAM (WAREHAM FIRE DISTRICT).

JAN. 14, 1908.

To Messrs. JOHN C. MAKEPEACE, EDWARD A. GAMMONS and WILLIAM A. LEONARD, *Water Commissioners of the Wareham Fire District.*

GENTLEMEN: — The State Board of Health received from you on Dec. 30, 1907, an application for the consent and approval of this Board, under the provisions of chapter 178 of the Acts of the year 1907, of the taking of certain sources of water supply for the Wareham Fire District, — namely, all the waters capable of being taken by wells bored or driven upon a certain parcel of land described in the application, the wells and the parcel of land in which they are situated being shown upon a plan submitted therewith.

It appears that the sources described in the application are intended to be those referred to in the reply of this Board dated July 9, 1907, and that the present application is made for the purpose of securing a more definite description of the location of the sources of supply than was practicable at the time of the previous application.

The Board has considered the application and the plan presented therewith and finds that the sources described are in the location approved in its communication of July 9, 1907, and the Board hereby consents to and approves the taking of water from the wells in the location described in your application of Dec. 28, 1907, and shown on the plan on file in this office, entitled "Wareham Water Works, 1907. Plan of Lot for Pumping Station and Wells and 30 Ft. Right of Way thereto. Scale 100′ = 1″. Edmund M. Blake, Engineer. December 4, 1907;" the lands in which the said wells are located being bounded, measured and described as follows: —

Beginning at a stone bound in the westerly side line of a travelled way which extends from the public way on the easterly side of the cemetery known as the Centre Cemetery in the said Wareham in a northeasterly and northerly direction towards Tihonet through land supposed to belong to the Tremont Nail Company which stone bound is distant about 5,700 feet northerly from the said cemetery by the line of the said travelled way and about 25 feet northerly from the place where the said travelled way crosses a brook. Thence from the said point of beginning running North 70° 54′ West 972.74 (nine hundred and seventy-two and 74/100) feet to a stone bound thence turning and running North 12° 15′ East 700 (seven hundred) feet to a stone bound thence turning and running South 77° 45′ East 902.10 (nine hundred and two and 10/100) feet to a stone bound thence continuing the last mentioned line to the westerly side line of the said travelled way thence turning and running by the said westerly side line of the said travelled way

by various courses but running generally South 12° West about 820 (eight hundred and twenty) feet to the point of beginning. Containing about 16.7 (sixteen and 7/10) acres and supposed to belong to the Tremont Nail Company.

Wellesley.

April 2, 1908.

To the Board of Water and Municipal Light Commissioners, Wellesley, Mass.

Gentlemen: — The State Board of Health received from you on Feb. 27, 1908, an application stating that the question of using a part of the water works reservation of the town of Wellesley as a playground has come before your board for consideration, and requesting the advice of the State Board of Health as to whether it would be wise to use any part of that land for that purpose; and in response to this request the Board has caused the locality to be examined by one of its engineers, and has considered the present condition of the water and the probable effect of the use of the area of land indicated for the purpose proposed.

The area which it is proposed to use for a playground borders the northerly side of Worcester Street, opposite Hastings Street, and is approximately 350 feet in length along Worcester Street and about 225 feet in width. The distance from the playground to the nearest well of the tubular-well system from which the supply of the town is chiefly drawn is a little over 400 feet, and its distance from Williams Spring, from which a part of the supply of the town is taken, is a little over 600 feet. There are several dwelling houses and a car barn on the southerly side of Worcester Street in this neighborhood, sewage from which is deposited in vaults and cesspools near this playground. There is also a group of buildings north of Worcester Street and east of Cedar Street, drainage from which probably affects the Williams Spring, while farther north, along Cedar Street, there are several groups of buildings, drainage from which may affect Williams Spring, the filter-gallery and the tubular wells.

The results of the analyses of the water of the tubular wells show that, while there has not been a noticeable increase in the quantity of organic matter present in this water, the quantity of chlorine and nitrates has been greater in recent years than in the first four or five years after the wells were first used, indicating that the water of your sources of supply is becoming increasingly affected by the sewage deposited upon or in the ground at and about buildings in their neighborhood. The water is safe for drinking, but unless the deterioration in quality shall be checked, the water may become unsafe for use.

The use of a part of the land purchased for the protection of your sources of supply as a playground would have a tendency to increase the

pollution of the water unless some efficient means of removing the sewage shall be provided. It is very important, in any case, that sewers be provided for the removal of the sewage from the dwelling houses and other buildings already constructed in this region, and when sewers have been provided for this locality it will probably be safe to use the area indicated as a playground. Until satisfactory means for the disposal of sewage for this region have been provided, the Board does not consider it advisable to locate a playground at the place proposed.

WEST BROOKFIELD.

MAY 7, 1908.

To Messrs. C. L. OLMSTEAD, J. G. SHACKLEY, E. K. HASKINS, *Water Supply Committee of the Town of West Brookfield.*

GENTLEMEN: — The State Board of Health received from you on April 24, 1908, the following application for advice with reference to a proposed water supply for the town of West Brookfield: —

At a recent town meeting the undersigned were appointed a committee to investigate and report upon a water supply for the town of West Brookfield. We have made certain preliminary investigations, and have under consideration several possible sources of supply, but before pursuing our investigations further we desire to secure, if possible, the assistance of your Board, and we would therefore respectfully solicit your advice with reference to the probable quantity and quality of the water to be obtained from the following sources: —

1. A ground-water supply to be obtained from the valley of Coys Brook, immediately above the village.
2. A ground-water supply to be obtained along the southeasterly shore of Wickaboag Pond.
3. A ground-water supply to be obtained from the southerly shore of Wickaboag Pond, not far from its outlet.
4. A gravity supply from a small stream entering Quaboag River from the north, just west of Ellis River.

Further investigations will be made of such of these sources as in your opinion seem to be the most desirable for the supply of the town.

In response to this application the Board has caused the localities indicated to be examined by its engineer and has considered the information available concerning the proposed sources of supply.

Of the sources mentioned the brook west of Ellis River is the only one from which a supply of water could be obtained for the town by gravity. The distance from the village to a point at which a reservoir might be located on that stream at a sufficient elevation to furnish a satisfactory pressure in the village is about 3½ miles, and the cost

of the necessary pipe line, together with the cost of a dam and reservoir, would be likely to make the cost of a supply of water from that source considerably greater than from either of the other sources mentioned in your application. Moreover, the quantity of water obtainable from that source at the elevation at which it would be necessary to locate a reservoir is limited, and its quality would be less satisfactory than that of water obtained from the ground.

An examination of the valley of Coy's Brook, the first source mentioned in your application, does not show any place in the neighborhood of the village where the conditions appear to be very favorable for obtaining a supply of good ground water.

The conditions at several places along the southeasterly and southerly shores of Wickaboag Pond, the second and third sources mentioned in your application, appear to be very favorable for obtaining an ample supply of ground water of excellent quality, so far as can be judged from surface indications.

As a result of its investigations the Board is of the opinion that the neighborhood of Wickaboag Pond is the most favorable locality in which to look for a water supply for West Brookfield. The Board would recommend, as the next step in your investigations, that you cause wells to be sunk at one of the favorable localities in the neighborhood of the pond to determine the character of the soil and the probable quantity and quality of water to be obtained there. It is possible that on the southerly shore of the pond good water can be obtained at a point slightly nearer the village than on the easterly shore, and it would probably be best to begin the tests in that region.

The Board will assist you in further investigations by making the necessary analyses of water, and will give you further advice in this matter when you have the results of further investigations to present.

West Springfield.

Sept. 3, 1908.

To the Board of Water Commissioners of the Town of West Springfield.

Gentlemen: — The State Board of Health received from you on Aug. 4, 1908, through your engineer, the following application for advice with reference to a proposed additional filter at Bear Hole Brook: —

I am authorized by the water commissioners of the town of West Springfield, Mass., to request your approval of the proposed addition to the filtration plant on Bear Hole Brook, as indicated in the accompanying plan.

The present plant has an area of one-sixth of an acre; the reservoir a capacity of two hundred and fifty thousand (250,000) gallons. It is now proposed to add an additional filter unit of equal area to that already in

use, locating this addition down stream, so as to make the reservoir and pumping station central between the two filters. It is proposed to raise the present dam a few feet, providing the head necessary for the delivery of water equal to the requirements of the two filters, providing each filter with an inlet-controlling apparatus to maintain a constant water level on the filters, and connecting the new unit with the present reservoir through an independent discharge-controlling apparatus similar to that now in use in the present filter. This new controlling apparatus and the main underdrains of the additional unit are to be made large enough to permit a moderate extension of the filter area, if necessary, in the future.

It is intended to operate the filters at a rate of three million (3,000,000) gallons per acre.

The underdrain system is to be of the same design as that already installed, and the sand will be obtained from the same pit as that from which the present filter was constructed.

The application is accompanied by a plan showing the present and proposed filters, together with the pumping station and reservoir for filtered water. The proposed new filter will have an area of 7,175 square feet, or about one-sixth of an acre, the same size as the present filter, and will be underdrained into the present reservoir for filtered water. The filter is to be an uncovered one, like the one now in use.

The Board has caused the locality to be examined by one of its engineers and has examined the plan of the proposed filter and the information presented therewith.

The present filter is not of sufficient capacity when operated at a reasonable rate to provide enough filtered water for the requirements of the town at all times, in addition to the quantity supplied from the original sources, and it is evident that an additional filter is needed. It is impracticable to make careful studies of the bacterial efficiency of the present filter, though so far as can be judged from the chemical analyses of the applied water, which naturally contains but little organic matter, and analyses of the effluent, good purification has thus far been effected at rates not exceeding 3,000,000 gallons per acre per day, the rate at which the present filter has been operated during much of the time since it was first installed.

If the proposed new filter shall be properly constructed, in accordance with the plan presented, using sand like that in the present filter, which has an effective size of .25 of a millimeter, it will, in the opinion of the Board, make it practicable for the town to filter all of the water which it is necessary to take from Bear Hole Brook at the present time.

Considering the circumstances, however, the Board advises that you continue the precautions necessary for preventing danger of direct pollution of Bear Hole Brook by sewage from dwelling houses or buildings

in the valley of the brook above by inspection and by the enforcement of the provisions of existing laws relative to the prevention of pollution of sources of water supply. The Board also recommends that you provide meters or other means for recording the quantity of water supplied to the town from all sources.

Nov. 5, 1908.

To the Board of Water Commissioners of the Town of West Springfield.

GENTLEMEN: — The State Board of Health has considered your application for advice as to the necessity of taking certain lands, with buildings thereon, situated in the valley of Bear Hole Brook, one of the sources of water supply of the town, for the purpose of protecting the quality of the water, the lands being in five separate parcels the location and area of which are approximately as follows: —

Land of Carlo Pesce, located on the easterly side of Millville Street, a short distance south of the boundary line between West Springfield and Holyoke, containing about 12 acres; land of Carlo Pesce, located on the westerly side of Millville Street, adjacent to the boundary line between West Springfield and Holyoke, containing about 23.5 acres; land of Patrick Cain, located on the southerly side of Bradley Street, between Prospect Avenue and Great Plains Road, so called, containing about 33.8 acres; land of Jerry Cain, located on the northerly side of Bradley Street, between said street and the extension of Great Plains Road, containing about 9.3 acres; and land of P. Scully, located on the westerly side of Millville Street, at its junction with Prospect Avenue, containing about .5 of an acre.

In accordance with the provisions of chapter 333 of the Acts of the year 1905 the Board gave a hearing at its office on Oct. 20, 1908, with reference to the proposed taking of the above-described lands for the purpose indicated, after publishing notice of the hearing in newspapers circulating in the town of West Springfield. The Board has also caused the locality to be examined and has considered the plan and information presented.

The water of Bear Hole Brook has but little color, and the quantity of organic matter normally present in the water is lower than in most surface waters, due, doubtless, to the fact that a large portion of it passes through the ground before entering the brook. When works were constructed for taking water from the brook, a filter was provided as a protection from possible effects of accidental pollution from the small population on the watershed, and the Board is informed that all of the water supplied to the town from Bear Hole Brook has been filtered through this filter, except for a short period in the early part of the present year, and that the area of the filters is now being doubled to

make them adequate for the filtration of all of the water supplied to the town.

The Board has also, in response to a request from your Board, adopted rules and regulations for the sanitary protection of the Bear Hole Brook watershed, as authorized by the statutes, and is informed that you have begun the enforcement of these rules.

An examination of the Cain places, located on either side of Bradley Street, indicates that the soil in that locality is probably composed of sand or gravel, and that vaults, cesspools or other possible sources of pollution can be so located and constructed that polluting matters, in order to reach the brook, must pass for such distances through the ground that they are likely to be purified. The pollution from the Pesce place, east of Millville Street, is not serious at the present time, and there is no pollution entering the brook from the Scully place, which is now unoccupied. The expense of making the necessary changes in vaults, cesspools and other sources of pollution upon these places would be very little as compared with the cost to the town of taking the lands.

At the Carlo Pesce place, west of Millville Street, the circumstances are such that it will be difficult to construct vaults or cesspools in satisfactory locations, or prevent, with reasonable certainty, the pollution of the brook from the buildings, and in the opinion of the Board it is desirable for the town to acquire this property and discontinue its use while the water supply of the town is taken from Bear Hole Brook.

The works now under construction by the city of Springfield for taking a supply of water from the Westfield Little River will doubtless be completed in less than two years, and as the main pipe of that system leading to Springfield passes through the populated portion of the town of West Springfield, it is likely that the town will find it more desirable to obtain its water supply, within a very few years in the future, from the Springfield works than to maintain the existing systems, especially since the capacity of the present systems is limited and will very likely require an expensive enlargement within a very few years.

By acquiring the Carlo Pesce property, west of Millville Street, making the changes suggested in vaults, cesspools and other possible sources of pollution on the other lands in question, enforcing the rules and regulations which have already been put in operation, and properly maintaining and operating the filters, the Board is of the opinion that the quality of the water of the Bear Hole Brook supply will be adequately protected and the water be safe for drinking; and the Board does not advise the town to take or acquire at present any of the other lands mentioned in your application.

The Board hereby approves the taking of the lands now or formerly

of Carlo Pesce, west of Millville Street, and adjacent to the boundary line between West Springfield and Holyoke, containing approximately 23.5 acres, said lands being bounded, measured and described as follows: —

Beginning at a point on the westerly side of Millville street in West Springfield, said point being at a stone wall on the line between land of P. Scully and Carlo Pesce, and running thence westerly along said stone wall about ninety (90) feet to a corner of the wall; thence running northerly along the wall about one hundred fifty six (156) feet to the end of said wall; thence running northwesterly on land of said Scully about four hundred twenty (420) feet to a corner of land of one Abbe; thence continuing northwesterly on said Abbe's land about one hundred seventy (170) feet to land of the New York, New Haven & Hartford Railroad; thence running northeasterly on land of said railroad about twenty-seven hundred eighty-eight (2,788) feet to a point on said railroad land; thence southeasterly on said railroad land about one hundred seventy (170) feet to the westerly side of Millville Street; thence running southerly on said westerly line of Millville street about twenty-eight hundred eighty-seven (2,887) feet to the place of beginning.

Containing twenty-three and 5/10 (23.5) acres, more or less.

WINCHESTER.

FEB. 6, 1908.

To the Water Board of the Town of Winchester.

GENTLEMEN: — The State Board of Health received from you on Jan. 2, 1908, a communication stating that there is a belief on the part of some of the inhabitants of Winchester that the town water supply is impure, and that the use of it causes disease, and requesting information as to its condition as shown by examinations made by this Board.

The artificial storage reservoirs from which the water supply of the town of Winchester is drawn derive their supply from uninhabited watersheds, all of which, excepting about 3 acres of the watershed of the middle reservoir, are included within the Middlesex Fells Reservation of the metropolitan park system. The watersheds of all the reservoirs consist for the most part of well-wooded uplands with very little swamp, so that the water entering the reservoirs is not only free from pollution but probably also naturally of good quality for water-supply purposes.

None of the reservoirs was prepared for the storage of water by the complete removal of the soil and organic matter from the area flowed, as has been the custom in the construction of reservoirs in more recent years. In consequence, the water entering these reservoirs has been stored in contact with the soil and organic matter in their bottoms, — a

condition which affects unfavorably the quality of the water and tends to foster growths of organisms which impart to water a disagreeable taste and odor.

The north reservoir has now been in use since 1874, and frequent mention is made in the reports of the water board of a disagreeable taste and oder in the water of that source. The quality of the water of that reservoir appears to have been very objectionable in the earlier years of its use, and this condition was no doubt rendered more objectionable on account of the serious pollution of one of the tributaries of the reservoir, which drained a densely populated area in Stoneham. This pollution was relieved considerably by the completion of the metropolitan sewerage system and the construction of sewers in the populated areas draining into Winchester reservoir, about twelve years ago, and subsequently this objection was wholly removed by the diversion from the reservoir of the stream which drained this populated area, a work which was apparently completed in 1901.

There has been a very decided improvement in the quality of the water of the north reservoir since 1895, though the water is still affected at times by growths of organisms and the disagreeable tastes and odors which they produce.

The water of the south reservoir, which was partially constructed in 1881 and completed in 1891, was evidently of very poor quality in the earlier years of its use on account of the organic matter taken up from its bottom and the disagreeable tastes and odors resulting from the presence of large growths of organisms. The quality of this water has, however, gradually improved in recent years, so that it now differs but little, on the whole, from that of the north reservoir.

The water of the middle reservoir, which was formed by flooding Turkey swamp, is much the poorest in quality of that of any of the reservoirs, but the water of this reservoir has also improved very considerably in the years since it was constructed. At the time of the construction of this reservoir the Winchester water board was advised by the State Board of Health to provide a separate waste pipe, so that the water of the middle reservoir need not be discharged into the south reservoir, but this provision was not carried out. There is no reason to doubt that the poor quality of the water of the middle reservoir has had an unfavorable effect upon the quality of the water of the south reservoir, and, while the difference in the quality of these waters at the present time is not great, the water of the middle reservoir is subject in a much greater degree to excessive growths of organisms than the water of the south reservoir.

The results of the examinations of the water of these reservoirs show

in general that there has been a decided improvement in the quality of the water of all of these sources in recent years as compared with their condition in the earlier years of their use. This gradual improvement appears at the present time to have reached its limit, and, judging from experience with other reservoirs of this kind, further improvement is likely to be very slow. They are all likely to continue to be affected at times, in common with the waters of other artificial reservoirs of this character and with many of the natural ponds, by growths of organisms which impart to water a disagreeable taste and odor, but it is not known that the use of water affected by such organisms is injurious to health.

If the reservoirs had been properly prepared for the storage of water in the beginning, by removing the soil and organic matter from their bottoms, the quality of the water would doubtless have been much better than at the present time, and growths of organisms and objectionable tastes and odors would have been of rare occurrence.

While the water of the Winchester reservoirs has been improving, and in recent years has been of better quality for drinking than in the earlier years of its use, it will doubtless continue to be unpalatable at times from the causes which have been described. It is probably impracticable to draw off and thoroughly clean the reservoirs at the present time unless arrangements can be made for securing a temporary supply in case of need from some other source; and the only other method by which trouble from taste and odor can be prevented is by filtering the water through sand.

The Winchester reservoirs are located in a public reservation which, though uninhabited, is likely to be used by an increasing number of visitors in the future. It will be essential to guard carefully the shores of the reservoirs and their watersheds from pollution by visitors to protect adequately the health of those using the water. Filtration of the water would be a further safeguard against the effect of pollution by visitors.

WOBURN.

JULY 2, 1908.

To the Hon. W. E. BLODGETT, *Mayor of the City of Woburn, Mass.*

DEAR SIR: — The State Board of Health received from you on June 16, 1908, a communication submitting for the approval of this Board a report and plans of your engineer, Mr. F. A. Barbour of Boston, outlining certain proposed improvements in the water supply of the city of Woburn. The improvements recommended in the report presented are the following: —

1. That the construction of a suction well be at once undertaken.
2. That an auxiliary supply of water from the area near Sucker Brook be installed before the end of the present summer.

3. That 3,000 meters be purchased and placed on the services within two years.

4. That a careful hydrant survey and investigation of the leakage from the distribution system be made to determine the sections in greatest need of improvement, and that from the results of such investigation a schedule of expenditure for the elimination of the cement-lined mains shall be adopted.

The estimated cost of the improvements at the source of supply, including a pump already purchased at a cost of $28,475, is $62,575.

The plans accompanying the application show the location of certain test wells in the neighborhood of Horn Pond and its tributary, Fowle Brook, the details of the proposed new suction well, so called, which is to be located southwest of the filter-gallery and about 90 feet therefrom, and the location of the proposed new wells and pumping station on the westerly side of the pond, about 1,000 feet northwest of the filter-gallery, together with the location of a force main from the wells to the proposed suction well.

The Board has caused the locality to be examined by its engineer and has carefully considered the plans and report presented. The Board has also examined the records of the yield of the filter-gallery in past years and the results of analyses of its water, and has considered the information furnished by a pumping test made by pumping from a group of wells on the westerly side of the pond in November and December, 1907, and the results of numerous analyses of the water of the test wells.

The evidence presented by your engineer shows that the quantity of water now being used by the city of Woburn probably averages 96 gallons for each person throughout the year. While the quantity of water required for use from the public supply is no doubt greater in a manufacturing city like Woburn than in towns where little or no manufacturing is carried on, there is no doubt that the quantity of water now being used in the city is excessive and could be restricted considerably by the introduction of meters, and the plan, as now recommended, of introducing meters on all services, is, in the opinion of the Board, a very desirable one for the city to adopt.

It is also probable, judging from the character of much of the distributing piping in Woburn, as described in the report of your engineer, that there is a large amount of leakage from the distributing mains, and that much water could be saved by an inspection of these mains and replacing those found most defective. It also is true that considerable water has been lost by leakage from the distributing reservoir in past years. In the opinion of the Board it is very important that measures be taken, as recommended, to prevent further loss of water by leakage from the distributing system.

The plan presented for enlarging the water supply of Woburn provides for the construction of a new well, known as a suction well, to be located about 90 feet from the present filter-gallery, and for putting in a group of tubular wells on the westerly side of Horn Pond, about 1,000 feet from the filter-gallery, and pumping water from these wells to the proposed new well, which is to receive also the flow from the present filter-gallery. From this suction well the water is to be pumped for the supply of the city.

It has long been evident that the greater portion of the water obtained from the present filter-gallery near Horn Pond has been derived by filtration through the ground from the pond, and the capacity of the filter-gallery has been materially increased in previous years apparently on two occasions by raising the level of Horn Pond. It is probable that a further increase might be obtained by a further raising of the level of the pond, and there is also little doubt that if the porous soil in which the filter-gallery is located extends to a considerable depth, a much larger quantity of water could be obtained in that locality by deepening the gallery or constructing a new and deeper filter-gallery or well in its immediate neighborhood.

Both of these methods of increasing your water supply are objectionable, however, on account of the danger that the deterioration in the quality of the water of which you are already informed would be increased thereby. While the deterioration now going on has not yet reached a point where it seriously affects the quality of the water, it is very desirable that further deterioration be arrested as soon as practicable, and the only remedy that the Board can suggest at present is to diminish the draft so that it shall not exceed the quantity being drawn from the filter-gallery before deterioration in the quality of the water began.

The proposed suction well, to be located about 90 feet from the filter-gallery and carried down to a depth of 13 feet below its bottom, would increase the flow from the territory which now feeds the filter-gallery, and would, in the opinion of the Board, tend to increase the deterioration in the quality of the water. The Board advises that the construction of the proposed suction well be omitted.

While it is evident that the greater part of the water drawn from the present filter-gallery is derived from Horn Pond, the quantity of water taken from that watershed up to the present time has not equalled the capacity of the watershed in a very dry season, and it is consequently practicable to increase materially the yield of your sources of supply if the greater quantity of water derivable from Horn Pond can be utilized. It is evident from the tests made last year that pumping at the

present filter-gallery induces a flow through the ground toward it from an extensive area around the southerly end of the pond, and it is also evident that this influence extends along the westerly shore of the pond to points in the vicinity of the mouth of Sucker Brook. The dense population along the eastern and northern shores of the pond makes it impracticable to secure water of good quality from the ground in that region, and the tests in the valley of Fowle Brook, made by your engineer, while not conclusive as to the impracticability of obtaining a good ground-water supply in that valley, indicate that it is doubtful whether water of good quality can be obtained from the ground in the immediate vicinity of the pond in that region.

The most favorable place for obtaining a good ground water from the neighborhood of the pond is along its westerly shore, near Sucker Brook, in an uninhabited region where the ground water is not yet exposed to pollution; and while the ground water in most of this region, as already stated, is influenced by pumping from your present filter-gallery, it is evident from the tests made here last year that the soil over a large area in this region is very coarse and porous, and that by putting in wells there a much larger proportion of the storage in the porous soil about the pond can be made available than is now obtainable by pumping at the filter-gallery alone. It is also probable that by pumping from wells on the westerly shore of the pond, in the location now proposed, the filtration of water from the pond into the ground can be materially increased. While there is no doubt that pumping water from wells in the location in which the test was made last year will have a tendency to diminish the quantity of water flowing toward the present filter-gallery, it is likely that the quantity of water obtainable from the wells will be considerably greater than can be obtained from the filter-gallery.

The valley of Sucker Brook and the westerly shore of Horn Pond for a long distance in its neighborhood are at present uninhabited, and the soil in this region, as already stated, is coarse and porous, and evidently well adapted to the purification of water by intermittent filtration. It is probable, under these circumstances, in the opinion of the Board, that it would be practicable to increase very considerably the quantity of good water available for the supply of the city by pumping water from Horn Pond upon suitably prepared areas in this region and allowing it to filter slowly through the ground to wells located near the shore of the pond. It is not unlikely that by the adoption of such a plan a quantity of water equal to the full capacity of Horn Pond and its watershed, and of a quality as good as that now obtained from the ground near the pond, could be secured.

Considering all the circumstances the Board is of the opinion that the best practicable plan of increasing the water supply of Woburn is to take water from the ground near the westerly shore of the pond, as proposed in the plan now presented. The Board would advise that the wells from which the supply is to be drawn be located in no case nearer than 100 feet from high-water mark in the pond, and that works of sufficient capacity be provided so that the draft on the present filter-gallery can be reduced to about half the quantity drawn therefrom during the year 1907. It is desirable that the new works be of sufficient capacity to supply all of the water required by the city in case of need.

It is of great importance to the city, if the use of water from the neighborhood of Horn Pond for the supply of the city is to continue for any considerable time, that the city shall secure control of a sufficient area of land in the watershed of Sucker Brook, and along the westerly and southerly shores of the pond, to prevent its occupation for dwelling houses or other purposes, and the Board would recommend that if works are begun for taking a water supply for Woburn from the ground in that region the control of a sufficient area of land for the protection of the supply be secured without delay.

The Board would again call attention to the importance of providing a covered reservoir to prevent the deterioration of the water in the distributing system and the offensive taste and odor which have been the source of much complaint for many years. Your attention has already been called to this matter in previous communications, but no action has yet been taken to provide an adequate remedy. The Board recommends that a suitable covered reservoir be constructed in connection with the proposed new works.

Wrentham (State School).

JAN. 14, 1908.

To the Board of Trustees of the Wrentham State School.

Gentlemen: — The State Board of Health received from you, through your engineer, on Dec. 31, 1907, an application desiring the advice of the Board as to taking water for the supply of the Wrentham State School from the ground north of the State highway leading from Walpole to Wrentham and near the northerly boundary of the property owned by the school, and in response to your application the Board has caused the locality to be examined by its engineer and a sample of the water of one of the test wells driven in this locality to be analyzed.

The results of the analysis show that the water is of good quality for all the purposes of a domestic water supply.

Regarding the quantity of water obtainable at this place the Board is unable to give you definite advice with the information thus far avail-

able. Water could be drawn freely from the test wells by means of a hand pump, and the indications are favorable for obtaining water from the ground in this locality in sufficient quantity for the supply of the school. The Board would recommend that before works are constructed for taking water from the ground at this place a further test be made by putting in additional wells and pumping from them for a period of several days, to note the effect on the height of the ground water and observe whether any changes take place in the quality of the water.

Another method by which the school can obtain a water supply is by a connection with the water works of the town of Wrentham, recently completed. The sources from which this supply is taken furnish water of excellent quality, and while the quantity obtainable is probably somewhat limited, there is no reason to doubt that it will be sufficient both for all reasonable requirements of the village and for the school for several years in the future, unless the population of the town should increase materially, which seems doubtful, or unless the population of the school shall become much greater than seems reasonable to expect at present.

Considering the circumstances the Board is of the opinion that if a satisfactory arrangement can be made with the town of Wrentham the town water works would be the most appropriate source from which to take a supply of water for the school.

SEPT. 3, 1908.

To the Board of Trustees of the Wrentham State School, Wrentham, Mass., DR. GEORGE L. WALLACE, *Superintendent.*

GENTLEMEN: — In response to your request for an examination of certain test wells which you propose to use as sources of water supply for the Wrentham State School, and advice as to the quality of the water, the Board has caused the wells and their surroundings to be examined by one of its engineers and samples of their waters to be analyzed.

The wells, which are 3 in number, are located in an area of swampy land east of the Wrentham Branch of the New York, New Haven & Hartford Railroad, and about 2 miles northeast of the village of Wrentham. The soil penetrated in driving the wells consisted of about 7 feet of peat, then clay and fine sand, beneath which the wells penetrated a gravelly stratum from 25 to 40 feet beneath the surface, from which water could be pumped quite freely.

The results of the analyses of the samples of water collected from two of the wells show that it is of good quality for purposes of public water supply. There is much doubt, however, as to whether, if water were drawn continuously from the ground in this locality for the sup-

ply of the institution, the quality of the water would remain satisfactory. It is the general experience that water taken from the ground in swamp or meadow land covered with a considerable depth of peaty soil, as in this case, deteriorates after a longer or shorter period of use, and becomes affected by an excess of iron. While it is not practicable to determine whether such would be the experience in this instance, the Board does not advise the construction of works for taking water from the ground in this locality unless it can be obtained from the hard land some distance from the swamp, where it would be unlikely to be affected by iron.

The Board has also, in accordance with your request, caused the water of a new well at the Snow place to be examined, and finds that the water was at this time very badly polluted and unfit for use. It is probable that the condition of the water was very unfavorably affected at this time by the work which had previously been carried on over and about the well, and a further examination will be necessary, after the work is completed and a considerable quantity of water has been pumped from the well, in order to determine definitely its probable quality.

The water of the old well at the Snow place, which was examined on June 11, was found to contain a larger quantity of organic matter than is found in good well waters, but was probably safe for drinking at the time that examination was made.

Nov. 12, 1908.

To the Board of Trustees of the Wrentham State School, George L. Wallace, M.D., *Superintendent.*

Gentlemen: — The State Board of Health received from you on Nov. 10, 1908, an application for advice with reference to taking a water supply for the Wrentham State School from the ground east of the Wrentham Branch of the New York, New Haven & Hartford Railroad, and about 2 miles northeast of the village of Wrentham, and in response to this application has caused the locality to be examined by its engineer and has examined the results of a pumping test made by pumping for a period of ten days, from October 28 to November 5, inclusive, from a group of wells in this locality.

The wells are located close to the upland on the easterly side of the area of swamp land in which tests were made during last summer, and all of the wells penetrated a porous stratum from which water could be drawn very freely. The quantity of water pumped from the wells continuously during the recent test amounted on an average to 400,000 gallons per day, and observations of the height of ground water in other wells in the neighborhood not connected with the pumps show that the level of the ground water was not lowered seriously during the test, the results indicating that an ample supply of water for the re-

quirements of the institution can be obtained from the ground in this locality.

Analyses of samples of the water collected from the wells at frequent intervals during the test show that it is in all respects of good quality for the purposes of a public water supply. The region about the wells is sparsely populated, and the purity of the water can be adequately protected by securing control of a moderate area of land about the wells.

In the opinion of the Board the source is an appropriate one from which to take a water supply for the Wrentham State School.

Yarmouth, Dennis, Harwich and Chatham.

Jan. 14, 1908.

To Messrs. Edmund M. Blake *and others, Petitioners for Incorporation as the South Shore Water Company.*

Gentlemen: — The State Board of Health received from you on Nov. 19, 1907, an application, under authority of chapter 75, section 117, of the Revised Laws, requesting the advice of the Board as to the use of wells near the shore of Long Pond at South Yarmouth as sources of water supply for the thickly settled portions of the towns of Yarmouth, Dennis, Harwich and Chatham, and has caused the proposed sources to be examined by one of its engineers and samples of the water from test wells near Long Pond to be analyzed.

The results of the analyses indicate that water of good quality for the purposes of a public water supply can be obtained from the ground in that locality.

Regarding the quantity of water to be obtained from wells near Long Pond a definite estimate cannot be made with the information now available. The test wells penetrated a gravelly soil, from which water could be drawn very freely, and the indications are favorable for obtaining an ample supply of water from the ground near Long Pond for all the requirements of the district which it is proposed to supply.

In the opinion of the Board the proposed source is an appropriate one from which to take water for the supply of the towns mentioned in your application. The Board would recommend that before works are finally constructed a further test be made by pumping from a group of wells near Long Pond for a period of several days, to determine more definitely the probable quantity and quality of water obtainable there.

Ice Supplies.

The following is the substance of the action of the Board during the year in reply to applications for advice relative to sources of ice supply: —

ACUSHNET.

MARCH 5, 1908.

To the Board of Health of the Town of Acushnet.

GENTLEMEN: — The attention of the State Board of Health has been called to the pollution of a small mill pond on the Acushnet River in the town of Acushnet, near the New Bedford boundary, from which ice is harvested for sale in the city of New Bedford and elsewhere, and the Board has caused the locality to be examined by one of its engineers and samples of the water and ice to be analyzed.

From this examination it appears that the pollution is caused by foul drainage from a rendering works situated in New Bedford on a small stream tributary to the mill pond, which enters the latter close to the dam at its outlet. It is evident from the examination that this small tributary is very badly polluted by the wastes from the rendering works, but, as the stream enters the mill pond near its outlet, the indications are that the polluted water does not mingle generally with the water of the mill pond, but is quickly carried through the raceway or over the dam, and the analysis of a sample of ice collected from the mill pond shows no evidence of pollution from the source indicated.

In the opinion of the Board the ice from this pond may safely be used for domestic purposes, provided no ice is cut within 200 feet of the dam or the mouth of the polluted brook, and provided, also, that all snow ice, including the first inch of clear ice that formed upon the pond, be removed before use, and that all ice containing particles of foreign matter be rejected.

The Board is informed that a sewer is now under construction which will receive the wastes from the rendering works and prevent the further pollution of the pond from this cause.

CONCORD.

JAN. 14, 1908.

To the Board of Health of the Town of Concord, MR. JOHN M. KEYES, *Chairman.*

GENTLEMEN: — In response to your request for an examination of an ice pond near the Cambridge turnpike, and advice as to its use as a source of ice supply, the Board has caused an examination of the pond and its surroundings to be made by one of its engineers and a sample of the water to be analyzed.

The results of the examination show no material change in the conditions affecting the use of the pond as a source of ice supply from those found at the time of the examination last year, concerning which the Board advised you as follows: —

The results of this examination show that the pond was not being injuriously polluted at this time, and that the ice, though containing a somewhat larger quantity of organic matter than is ordinarily found in good ice, was safe for domestic use. The Board would recommend, however, that the snow ice and the first inch of clear ice be removed before using and that all ice containing particles of foreign matter be rejected.

HOLYOKE.

DEC. 3, 1908.

To the Board of Health of the City of Holyoke.

GENTLEMEN: — The State Board of Health received from you on Nov. 2, 1908, a request for an examination of certain sources of ice supply located in and about the city of Holyoke, and in response has caused the various sources mentioned to be examined by one of its engineers and samples of their waters to be analyzed.

Of the sources mentioned, Ashley Pond in Holyoke and Leaping Well Reservoir in South Hadley are used as sources of water supply, and the ice taken therefrom is evidently of good quality for domestic purposes. The same is true of the ice taken from Middle Pond in Belchertown, which contains water of good quality derived from a very sparsely populated watershed.

Of the remaining sources, two are located in Chicopee, viz., Willimansett Brook and Dauphinaus Pond. The pond from which ice is taken on Willimansett Brook does not appear to be exposed to serious danger of direct pollution, and ice harvested from it under existing conditions may safely be used for domestic purposes. Dauphinaus Pond, located on a small tributary of Crowfoot Brook, appears also to be a safe source of ice supply under present conditions.

The sources located in Holyoke are Ashley Pond (already referred to), Street's Ponds, three small ponds on Tannery Brook (known as Bray's Pond, McNee's Pond and Cote's Pond) and the Connecticut River.

Street's Ponds, located in the extreme northerly part of the city, drain a sparsely settled region and may safely be used as sources of ice supply for domestic purposes.

Of the ponds on Tannery Brook, the upper one (known as Bray's Pond) is very badly polluted, and the use of ice cut therefrom should be prevented. The waters of the other two ponds on this stream (Cote's Pond and McNee's Pond) are exposed to considerable danger of pollution from the buildings on their watersheds, and are not desirable sources of ice supply. Ice which might safely be used for domestic purposes might be obtained from these ponds by removing all snow ice,

including the first inch of ice that formed upon the ponds, and rejecting all ice containing particles of foreign matter.

The Connecticut River receives considerable direct pollution from the sewage of cities and towns above Holyoke, and even if the ice is cut above the outlets of any of the Holyoke sewers, the river cannot be regarded as a safe source from which to take ice for domestic purposes unless all snow ice, including the upper inch of clear ice formed on the stream, shall be removed before using, and all ice containing particles of foreign matter be rejected.

The sources located in South Hadley, aside from Leaping Well Reservoir, already referred to, are Buttery Brook, Chapin Pond and Newton-Smith Ponds, so called.

The pond from which ice is taken on Buttery Brook is located below Buttery Brook Reservoir, one of the sources of water supply of the town of South Hadley. The watershed contains a large population, and the attention of the water board of the town has been called to the importance of preventing the pollution of the water from the large number of buildings on its watershed. The ponds on this stream are not desirable sources of ice supply, and if their use is continued it should be upon the condition that all snow ice, including the first inch of ice forming upon the ponds, shall be removed and all ice containing particles of foreign matter rejected, thus retaining for use only the clear ice forming beneath the first inch and free from particles of foreign matter.

The Newton-Smith Ponds, located on Jacob's Hollow Brook, appear to be free from serious danger of pollution, and in the opinion of the Board ice taken from these ponds may safely be used for domestic purposes.

Chapin Pond, located on the easterly side of Newton Street, is exposed to considerable danger of pollution from the dwelling houses on its watershed and drainage from the adjacent street, and an analysis of the water shows evidence of serious pollution. In the opinion of the Board it is not a safe source from which to take ice for use for domestic purposes, where it may come in contact with food or drinking water.

LEXINGTON.

Nov. 5, 1908.

To the Board of Health of the Town of Lexington, Mass.

GENTLEMEN: — In accordance with your request of Oct. 13, 1908. the State Board of Health has caused two sources of ice supply, known respectively as Granger's Pond and Simonds Pond in the town of Lexington, to be examined and samples of their waters to be analyzed.

Granger's Pond is a small reservoir formed by a dam on Vine Brook, which drains a thickly populated area in the village of Lexington, where there are no sewers. An examination of the banks of the stream above the pond shows that it is exposed to pollution by sewage from many buildings along its course, and an analysis shows that its waters are considerably polluted. In the opinion of the Board ice from this source cannot be used with safety where it may come in contact with food or drinking water.

Simonds Pond is polluted to a somewhat greater extent than Granger's Pond, evidently from the buildings on the easterly side of Burlington Street near the pond or its feeders. It may be practicable to prevent danger of the direct pollution of the pond from the buildings on the watershed, and if that were done it would be possible to obtain ice from this source which might safely be used for domestic purposes. It would be necessary, however, to use only the clear ice beneath the first inch which formed upon the pond, and to reject all snow ice, including the first inch of clear ice, and all ice containing particles of foreign matter. Unless the pollution of this pond shall be prevented, its further use as a source of ice supply for domestic purposes should be discontinued.

West Springfield.

Jan. 14, 1908.

To Mr. S. A. Bragg, *West Springfield, Mass.*

Dear Sir: — In response to your request of Dec. 28, 1907, for an examination of the water of an ice pond on Bagg Brook in West Springfield, and advice as to the use of ice from that source for domestic purposes, the Board has caused the locality to be examined by one of its engineers and a sample of the water of the brook to be analyzed.

The results of the examination show that at the present time the watershed of the ice pond contains apparently but one dwelling house, situated at the extreme upper end of the watershed, from which it is unlikely that the brook will be polluted to such an extent as to affect the ice gathered therefrom.

In the opinion of the Board the pond may safely be used as a source of ice supply for domestic purposes. The Board would recommend, however, that all snow ice and the upper inch of clear ice be removed before using, and that ice containing particles of foreign matter be rejected.

Sewerage and Sewage Disposal.

The following is the substance of the action of the Board during the year in reply to applications for advice relative to sewerage and sewage disposal: —

Attleborough.

Dec. 30, 1908.

To the Sewerage Committee of the Town of Attleborough.

Gentlemen: — The State Board of Health received from you on Dec. 7, 1908, the following application for advice with reference to the disposal of the sewage of the town of Attleborough: —

At a special meeting of the voters of the town of Attleborough held on June 23, 1908, a committee was appointed and instructed "to frame a special act to be presented to the Legislature providing for the installation of a sewer system and investigate in regard to all details of assessments, maintenance, construction, etc., and report to some future meeting, to be held before the sitting of the Legislature."

The committee have examined several locations in an endeavor to find the best place at which to locate filter beds. Test pits have been dug at these places and samples of the material taken under the direction of the chief engineer of your Board. The only location at which material of a suitable quality and in sufficient quantities for the future growth of Attleborough has been found is located partly in the town of Attleborough and partly in the town of Seekonk, as shown upon the accompanying plans.

It is the opinion of this committee that it is desirable that the town of Attleborough be authorized by the Legislature to acquire the land described in section 3 of the proposed act, a copy of which is herewith submitted, the committee having already secured for the town an option upon the greater part of this area.

The committee therefore requests the advice of the Board upon this matter.

The application is accompanied by plans showing the location of the proposed sewage-disposal area, the contour of its surface and the location of numerous test pits dug in various parts of the area to determine the character of the soil.

The land in question is located between the Providence Division of the New York, New Haven & Hartford Railroad and the Seven Mile and Ten Mile rivers, at the boundary line between the towns of Attleborough and Seekonk and adjacent to the boundary line between those towns and the city of Pawtucket, R. I.

The Board has caused the locality to be examined by its engineer and samples of soil from the test pits to be analyzed, and has considered the plans presented.

The surface of the northern and eastern portions of the area is quite uneven, and the examinations have shown that, while the soil of those portions is in some places of good quality for sewage purification, it

is in most places either too fine for that purpose or is composed of layers of materials of different degrees of fineness, which would make the construction of filter beds difficult and expensive.

The western and southern portions of the area have a much more even contour, and contain, beneath a thin surface layer of loam and subsoil, a very coarse sand or gravel of excellent quality for the purification of sewage by intermittent filtration. Much of the area containing the soil best adapted to sewage purification lies within the limits of the town of Seekonk, but in an uninhabited section of that town quite remote from any town highway or thickly settled district. In the opinion of the Board the area selected is an excellent one for sewage-disposal purposes, and the discharge of such an effluent as can be obtained from sewage filters constructed in this region into the Ten Mile River will not be objectionable.

While the area which it is now proposed to use for the disposal of the sewage of Attleborough is located at a considerably greater distance from the thickly settled part of the town than the areas which have formerly been considered, it is probable, in the opinion of the Board, that the sewage can be disposed of more satisfactorily and at no greater expense at this area than at any of those that have previously been considered. The amount of land which it is proposed to acquire for the purpose, as shown on the plan submitted, is, in the opinion of the Board, a reasonable one.

The Board recommends that detailed plans for the sewage-disposal works be submitted for consideration before the construction of works is begun.

Canton (Draper Bros. & Co.).

June 4, 1908.

To Messrs. Draper Brothers & Co., *Canton, Mass.*

Gentlemen: — The State Board of Health received from you on May 4, 1908, through your engineer, — Mr. William S. Johnson of Boston, — the following application for advice with reference to a proposed plan for purifying the wastes from your mill at Canton: —

Judging from the measurements and analyses which have been made under your direction, the quantity of wastes for which it is necessary to provide purification works does not exceed 12,000 to 15,000 gallons per day. The character of the wastes is such that much of the objectionable matter will be removed by sedimentation.

The plans submitted provided for the construction of a sedimentation tank having a capacity of about 15,000 gallons, from which the supernatant liquid will flow to filter beds to be composed either of sand or of cinders to a depth of 3 feet above the underdrains. A sludge bed sufficient to hold

the contents of one of the tanks will also be provided, this bed to be constructed of cinders.

The character of the wastes and the conditions below the mill are such that it seems probable that the settling tank will purify the wastes to such an extent as to prevent the noticeable pollution of the Neponset River. We propose, therefore, with your consent, to omit the construction of the filter beds for the present, but to construct the settling tank and sludge bed in such a manner that the filter beds can be added whenever it is found necessary or desirable. If the construction of the filter beds is deferred, they can be constructed at a much less expense, since a considerable quantity of cinders is produced at the mill, and in a comparatively short time enough filtering material will be secured for the construction of the beds. If the beds are constructed immediately it will be necessary to construct them of sand hauled a long distance at a large expense.

The plan accompanying the application shows a settling tank built in two compartments, having a total capacity of a little over 17,000 gallons; a sludge bed, having an area of about 4,000 square feet, to receive the sludge from the settling tanks; and 3 filter beds, each having an area of .3 of an acre, provided with underdrains discharging into the adjacent brook.

The Board has carefully examined the plan presented and the information available as to the quantity and character of the wastes from this mill.

The settling tanks should be so arranged that the water will be drawn from them at a depth sufficiently below the surface not to draw off the accumulation of grease and other floating matters with the effluent. The floating matters should be removed separately and not mixed with the sludge. If the grease is properly removed it is probable, in the opinion of the Board, that the filter beds will serve the purpose.

CHELMSFORD (NORTH CHELMSFORD).

JUNE 4, 1908.

To the Board of Selectmen of the Town of Chelmsford, Mr. D. F. SMALL, *Secretary.*

GENTLEMEN: — The State Board of Health received from you on May 14, 1908, an application for advice as to the disposal of the sewage of the town hall and two school buildings in its neighborhood, in the village of North Chelmsford, accompanied by a plan showing two possible lines for a sewer to Stony Brook, — the outlet according to one plan to be at the Middlesex turnpike, and, according to the other, at a point east of Middlesex Street about 400 feet from the mouth of the brook; and in response to this application the Board has caused the locality to be examined by one of its engineers.

Stony Brook is badly polluted at times, and it will not be desirable to provide permanent outlets for sewage into that stream at Middlesex turnpike or elsewhere, unless, possibly, at some point between Middlesex Street and the mouth of the brook. It is probable that if either of the proposed sewers should be built requests would soon be made for permission to connect other buildings therewith, and it will be far better and more economical, in the opinion of the Board, for the town to plan a general system of sewerage for this village before entering upon the construction of any sewers therein.

When a satisfactory plan has been prepared it will then be practicable to build sewers from time to time in such streets as require sewerage, and provide suitable outlets therefor.

The Board would recommend that such a plan be prepared without delay, and upon presentation of the plan the Board will again examine the locality and advise you as to the disposal of the sewage of the village and of the districts requiring sewerage at the present time.

Nov. 5, 1908.

To the Board of Selectmen of the Town of Chelmsford.

GENTLEMEN: — The State Board of Health received from you on Sept. 22, 1908, an application for advice as to a proposed system of sewerage and sewage disposal for the village of North Chelmsford, accompanied by a plan showing the location of the proposed sewers and outlets.

The plan provides for collecting the sewage in a system of pipe sewers discharging at five outlets, — three into Stony Brook and the others into the Merrimack River below Stony Brook. The points of discharge of the two outlets into the Merrimack River are located approximately 400 and 1,100 feet east or down stream from the mouth of Stony Brook.

The Board has caused the locality to be examined by one of its engineers and has considered the plan presented and analyses of the waters of Stony Brook near the proposed main sewer outlets below the village. The outlet below the State highway, near the central portion of the village, would discharge into the stream at a point where at times of low flow there is frequently very little water in the bed of the brook on account of the diversion of the water above through a canal to the mills below. The discharge of sewage at this point would, in the opinion of the Board, be very objectionable.

The proposed main outlets into Stony Brook below the village under ordinary conditions would probably not be objectionable for a number of years, and under such conditions their use will be permissible, but the brook is very badly polluted by wastes discharged from the mills above, and analyses of the water during the past summer show that

at times of dry weather the stream is polluted to such an extent that if sewage were added a serious nuisance would very likely be created.

The very limited quantity of sewage which might be derived from the town hall and school buildings in the portion of the village on the westerly side of the brook might be discharged temporarily at the proposed outlet without very serious objection, but the Board recommends that the permanent outlets be carried farther down the brook and discharged into the stream at the point where it enters the Merrimack River, and that the outlets be so placed that the sewage will be quickly carried out into the Merrimack River by the current of the stream and avoid polluting the banks.

The two outlets east of Stony Brook are not likely to be objectionable if they are located beyond the limit of extreme low water in the river, so that they will be covered with water at all times.

It is understood that the system is to be constructed on the separate plan and that storm water and ground drainage are to be excluded from the sewers so far as practicable. It is very important that this plan be followed in the construction and operation of the system, since, by excluding storm water and ground drainage, sewers of much smaller size will serve satisfactorily for the removal of the sewage, while the storm water can be discharged into Stony Brook or its tributaries at any convenient points in the village without danger of creating objectionable conditions.

The Board recommends that the sewers in the district west of Stony Brook be extended as soon as practicable to serve that part of the village nearest the water works, and that all of the dwelling houses in the region of the water works be connected to the sewers as soon as possible to prevent the pollution of the ground water.

Clinton.

Sept. 3, 1908.

To the Metropolitan Water and Sewerage Board, 1 Ashburton Place, Boston, Mass.

Gentlemen: — In response to your request for advice as to improving the efficiency of the sewage purification works at Clinton, the Board has caused the operation of the works to be carefully observed, and has examined the records kept by your Board, showing the quantity of sewage pumped, the quantity applied to the various filters, the height of the ground water, etc., and has considered the results of numerous analyses of samples of the sewage and effluent collected at frequent intervals since the works were established.

Early in the investigation in June, 1906, underdrains were constructed

in beds Nos. 2, 5 and 6, and distributing troughs were installed on beds Nos. 2 and 5 in order to test the effect of a more equal distribution of the sewage on the filters; and at the same time an experimental filter for the refiltration of the effluent was established near the outlet of the main underdrain.

The quantity of sewage discharged upon the Clinton filtration area has varied greatly in different years. The minimum daily amount was 627,000 gallons, in the year 1900, the first year of the operation of the works. In the year 1905, however, the quantity was but little larger, amounting to 642,000 gallons per day, as shown by the records kept by your Board. The maximum amount in any year was 874,000 gallons per day, in 1907, but the quantity discharged upon the filters in the second year of the operation of the works, 1901, was 836,000 gallons per day, or about 5 per cent. less than the amount treated last year. There is also a wide variation in the quantity of sewage discharged upon the filters in different months of the year, the maximum amount discharged in any month in the year 1907 being about 1,400,000 gallons per day, in the month of November, while in the month of minimum flow the quantity averaged 528,000 gallons per day.

The total area of filter beds is 23½ acres, so that the average quantity applied per acre in 1907 was about 37,000 gallons per day. The sewage contains considerable manufacturing waste, largely effluent from the scouring of wool, and is exceptionally strong in organic matter and fats, but though the sewage is strong the quantity applied to the filters is not excessive.

Good purification was effected by the filters for the first three years of their use, but nitrification then gradually decreased, and the quality of the effluent has become very poor, being characterized by the presence of a considerable quantity of organic matter and an excessive quantity of iron, evidently derived by reduction from the soil of the filter beds.

Records of the operation of the filters show that it has been the general custom, until July, 1907, to apply the sewage to the filter beds in very large doses at infrequent intervals. The maximum number of doses applied to any filter bed in the year 1900 was eight, and the average number three or four. The average size of the dose was over 300,000 gallons per day, and often in the winter and spring months was as high as 500,000 gallons, and even more. This method of dosing was continued until July, 1907, with slight intermissions in 1903 and 1904, when smaller and more frequent doses were applied for a time.

The sewage is discharged upon the filters through a single outlet at the side of each filter, excepting in the case of beds Nos. 2 and 5, which are provided with distributing troughs, as stated above. When

large doses were applied to the filters they were usually covered, even in the summer, to a considerable depth, while in winter some of the beds were covered with sewage continuously for long periods. Since the change made in the method of dosing, about a year ago, the sewage does not usually cover fully any of the beds properly underdrained, excepting beds Nos. 2 and 5, so that a part of these filters receives little or no sewage during much of the year, making the rate of filtration over the area which the sewage actually reaches much greater than the average rate over the entire area.

Very little underdrainage was provided in the filters when the works were first constructed in the belief that on account of the coarseness of most of the material more thorough underdrainage was unnecessary. Soon after the operation of the works was begun, however, it became evident that additional underdrainage was necessary in the central portion of the area, and an underdrain was extended to that portion. It is evident, however, both from measurements of the flow from the underdrains and an inspection of the conditions about the filters, that much of the effluent is not collected into the underdrains, but finds its way through the soil to adjacent water courses. Moreover, recent observations of the heights of water in various wells about the area show that the filter beds are not well underdrained, and a recent examination of one of the underdrains shows that it is clogged and practically useless.

As a result of the examinations the Board is of the opinion that the causes of the inefficient purification of the sewage applied to the Clinton filter beds are (1) the application of excessive doses of sewage to the filter beds, (2) the lack of adequate means for an even distribution of the sewage upon the filters, and (3) inadequate underdrainage.

The size of the doses applied to the filters up to the middle of last year was too great for the proper oxidation of the sewage, especially in the filters affected by inadequate underdrainage, and while fairly good purification was obtained in the first few years after the filters were first used, the quantity of organic matter present in the effluent was larger than is found in good sewage effluents. Analyses of the sand of some of the filters indicate that organic matter has been stored in the filters in considerable quantity. With the accumulation of organic matter and the continued application of excessive doses of sewage to the filters and clogging of the underdrainage, the quality of the effluent rapidly deteriorated.

Since the change in the method of operation of the filters, inaugurated last year, some improvement has taken place in the effluent, but until efficient underdrainage is provided it is unlikely that satisfactory purification can be effected. The examinations show that a portion of the

west underdrain is clogged in Filter No. 11, interfering greatly with the underdrainage of the filters above and adjacent thereto, and it is also evident that the other branch of the west underdrain is not rendering efficient service, and that the east underdrain does not provide adequately for the underdrainage of the filters tributary thereto.

In providing additional underdrainage the main object is to lower the level of the water in the filters as low as practicable in order to admit all the air possible for the proper oxidation of the sewage. It is probable that the filters contain much stored organic matter, and while the material of which they are composed is as a rule coarse and porous, it is evident that they are stratified to a considerable extent. Under these conditions it is desirable to provide more complete underdrainage than might otherwise be regarded as necessary.

Test wells near the underdrains show that the ground is saturated to a depth of from 4 to 6 feet above the underdrains, and to a depth of from 3 to 4 feet higher than was the case in the early years, when better purification occurred. This is probably due to accumulation of iron rust around the underdrains, which prevents entrance of water with sufficient freedom. At present the west underdrain has a length of about half a mile above its outlet and the east underdrain a length of about one-quarter of a mile. Obstruction occurring in any part of these great lengths can with difficulty be located, and when located can be removed only by putting out of use a large number of beds. To render the beds more efficient and more readily kept in order, the Board would recommend including but three or four beds in one system of drainage, with outlets on the southeasterly side of the area, with the exception of the four northwesterly beds, which should drain towards the northeast.

The general system for proposed drainage is presented on the accompanying plans.

The top of underdrains should be about 5 feet below surface of beds.

When more thorough underdrainage has been provided the sewage will have a tendency to sink more rapidly into the filters than at present, and in order to secure a thorough distribution of the sewage a much larger number of inlets will have to be provided than exists at the present time. Three for each of the large beds, as shown upon the plans, will probably be sufficient.

It is probable that the filters have stored a considerable quantity of organic matter, and in their future operation it will be necessary to exercise all the care practicable to restore them to a condition in which they will purify the sewage satisfactorily. While with suitable underdrainage, a proper distribution of the sewage and the application of

reasonable doses, as now practiced, improvement will follow, time may be necessary before satisfactory results can again be attained. Under the circumstances it is very important that the whole area of filters be put into a condition for regular use as soon as practicable.

EASTHAMPTON.

OCT. 1, 1908.

To the Board of Selectmen of the Town of Easthampton, Mr. FRED J. GEOUGH, *Clerk.*

GENTLEMEN: — In response to your request of Aug. 5, 1908, for advice as to a proposed change in the outlet of a sewer in Mill Street, now discharging into the Manhan River on the north side of the stream at a point above the dam, to a new outlet below the dam, the Board has caused the locality to be examined by one of its engineers and has considered the plan presented.

You state that you propose to use the new outlet only as a temporary means of disposal, to avoid the pollution of the river above the dam, but that you intend ultimately to pump the sewage into the main system of the town. It appears that there is also a sewer on the south side of the river in this region with which there are about 10 house connections and which now has an outlet into the river just below the dam.

The quantity of sewage discharged at the two outlets may amount at the present time to from 5,000 to 10,000 gallons per day, and the Board is of the opinion that, while it may be permissible to use these outlets for a short time, provision should be made as soon as practicable for pumping the sewage from these districts into your main sewerage system.

It is possible that, in connection with pending changes and improvements in your sources of water supply, it may be necessary to make changes at your water works pumping station, and the Board recommends that, in connection with such changes, provision be made for pumping the sewage from areas now discharging into the river near the pumping station into the main sewer system of the town, and that the further discharge of any part of the sewage of Easthampton into the Manhan River be discontinued.

GRAFTON (GRAFTON COLONY FOR THE INSANE).

MAY 7, 1908.

To the Board of Trustees of the Worcester Insane Asylum, Worcester, Mass., DR. E. V. SCRIBNER, *Superintendent.*

GENTLEMEN: — The State Board of Health received from you on May 5, 1908, an application for advice with reference to proposed plans for the disposal of sewage at the Grafton Colony for the Insane, con-

nected with the Worcester Insane Asylum, which provide for collecting the sewage of all the buildings — except that from the power house and from one other building in its neighborhood — into a main sewer, and for conveying it by gravity into the valley of a small tributary of the Quinsigamond River in the southwesterly part of the institution grounds, and disposing of it there by intermittent filtration; and in response to this application the Board has caused the present and proposed systems of sewage disposal at that institution to be examined by its engineer.

The examination of the present method of sewage disposal at the various buildings shows that the devices in use are unsatisfactory, and that the neighboring streams are being considerably polluted by unpurified sewage from the various buildings.

The water supply of the institution is taken from the ground near the Assabet River, and recent tests indicate that it is likely that a sufficient supply of good water for the institution can be obtained in that valley for several years in the future, and it is important that sewage be diverted from that watershed.

There does not seem to be any area of land within the limits of the territory controlled by the institution which contains soil of suitable character for the purification of sewage except in the neighborhood of the wells from which the water supply of the institution is drawn. It will probably be best, under the circumstances, to locate the sewage purification works in the valley of the small tributary of the Quinsigamond River in the southwesterly part of the territory controlled by the institution, as now proposed, since practically all of the sewage of the institution can be conveyed to the area indicated by gravity, and it will be necessary in any case to haul the material for the construction of filter beds. It appears from the report of your engineer that filter beds of sufficient area to purify all of the sewage of the hospital can be constructed in the locality indicated at reasonable expense, even though it will be necessary to haul the material for the purpose from a considerable distance.

The Board would recommend that the works be constructed without delay, and that all the sewage of the institution be conveyed to this area for disposal. The power house and a building in its neighborhood are probably at too low a level to be served by the proposed sewer by gravity, and it will be necessary to pump the sewage from these buildings into the main sewer. The sewage from these buildings might be disposed of temporarily upon the filter beds near one of the tributaries of the Assabet River now used for the purpose, but it is not desirable to use these filter beds permanently.

The Board would also recommend that, in the location of new build-

ings to be used in connection with this institution in the future, provision be made if possible for discharging the sewage into the general system, so that it may all be disposed of at one place.

Hyde Park (Tileston & Hollingsworth Company).

Aug. 6, 1908.

To the Tileston & Hollingsworth Company, Mr. Amor Hollingsworth, *President, Boston, Mass.*

Gentlemen: — The State Board of Health has considered your communication of Aug. 5, 1908, relative to a further time in which to consider the possibility of effecting the purification of the wastes from your mill at a less expense and refer the question to other engineering authorities, and, having consulted with the Attorney-General relative thereto, has voted that it will consider further plans for the disposal of your wastes if presented on or before Oct. 1, 1908.

Lowell.

June 15, 1908.

To Mr. George Bowers, *City Engineer, Lowell, Mass.*

Dear Sir: — The State Board of Health received from you on May 6, 1908, the following communication relative to the sewerage of the city of Lowell: —

> At a meeting of the committee on sewers of the city of Lowell, held Friday, May 1, it was voted to instruct the city engineer to ask advice of the State Board of Health in regard to the proper method of drainage for that part of Lowell known as Wigginville and South Lowell. This is the same part of Tewksbury that has petitioned the State Board of Health in former years.

Subsequently, on May 27, in response to a request for an outline of your proposed plans, a plan was submitted showing the districts of Wigginville and South Lowell and certain elevations of the ground and of the Concord River and a tributary brook in this region. On June 2 a further communication was received, giving an outline of your proposed plans of sewerage and sewage disposal for these districts, as follows: —

> In explanation of the plan sent you showing the Oaklands, Wigginville and South Lowell, would say that there are three different propositions for the disposal of the sewage of Wigginville and South Lowell.
>
> 1. Allow the sewage to enter the Concord River in two or more places; one, northerly of the Lowell & Andover Railroad, where it crosses Lawrence Street; another, near the intersection of Acton and Billerica streets, not far from the brook that now drains that section.
>
> 2. Collect all the sewage of Wigginville, carry it down Lawrence Street

to the Boston & Maine Railroad crossing; thence beside the Concord River on land belonging to the Lowell & Andover Railroad, and empty it into the sewer already laid in Rogers Street.

3. Collect all the sewage and carry it by a main sewer southerly under the Boston & Maine tracks to land owned by the United States Cartridge Company, which is the most southerly land in the city of Lowell.

The drainage area of Wigginville lying between the Lowell & Lawrence branch and the Lowell & Andover main track is about 121 acres.

The drainage area of South Lowell in the city of Lowell is about 295 acres. In Wigginville and South Lowell there are now about 265 dwelling houses.

Work has already been commenced on some of the sewers in Wigginville, and an early solution of the manner of disposal of sewage is very earnestly desired.

You have also submitted to the Board a profile showing the approximate line for a proposed main sewer for the drainage of these districts, extending from the neighborhood of the outlet of the brook near Bolton Street to a connection with the Rogers Street sewer near the easterly bank of the Concord River, and a profile of a sewer in the valley of the brook discharging into the Concord River opposite Bolton Street.

Beyond the information furnished by the plan and profiles presented, it does not appear that further information is available as to the topography and elevation of these districts, though the construction of sewers and drains has already been begun there by the city government. It is understood that the separate system of sewerage is to be adopted and followed in providing sewerage in these districts.

The Board has caused the locality to be examined by its engineer and has examined the plans and information presented therewith.

The elevation of the greater part of the land in the districts under consideration is such that sewerage can be provided without difficulty, and the sewers can be laid at satisfactory elevations and grades; but the plan shows that a part of these districts bordering the Concord River, in which several dwelling houses have already been constructed, lies at a very low level with respect to the river, and an examination shows that much of this area is poorly drained and subject to flooding at times of high water in the river. It is impracticable to provide efficient drainage for these districts under the conditions that now exist there; and furthermore, if sewers should be built in Billerica Street and portions of adjacent streets, and in certain streets in the valley of the brook entering the river opposite Bolton Street, shown upon the plan, they would necessarily be laid below the level of the ground water. Under these conditions it would be very difficult, if not impracticable,

to prevent the leakage of a great quantity of water into the sewers, greatly increasing the cost of collection and proper disposal of the sewage, besides perhaps interfering with the efficient operation of the sewers and rendering the city liable for other considerable expenses.

Considering the circumstances, the Board would recommend that, before a sewerage system is constructed in this district, the streets be raised, where necessary, to a sufficient elevation above the river, in general as much as 5 feet above the level of the freshets, so as to provide adequate drainage at all times, and that a minimum elevation for buildings in this district be prescribed which shall be such as will allow for their proper drainage.

There is no doubt that the separate system of sewerage is best adapted for the drainage and sewerage of these districts, since the storm water and ground drainage can be readily disposed of by discharging it directly into the river or local water courses without objection and at a comparatively small cost; while much smaller sewers will be required for removing the sewage than would be the case if rain water were also removed in the same pipes.

The Board would recommend that the city secure control of the brook flowing through this district and of its tributaries, and that these be kept in a condition suitable for the removal of all drainage from this region. The control of these streams can be secured now, and the necessary changes made in their courses, at far less expense than will be the case if this necessary work is deferred until the district becomes more thickly settled.

Of the plans suggested for the disposal of the sewage from these districts, that of discharging it directly into the Concord River at one or two outlets in this region would be the least expensive, in the beginning at least; but trouble has already been experienced from the discharge of sewage into the river above the lowest dam, and the stream receives so much pollution from manufacturing wastes and in other ways that it already appears to be a source of nuisance at times of dry weather in portions of its course through the city. In view of the circumstances, the river is not, in the opinion of the Board, a proper place of disposal for any considerable quantity of sewage, such as would evidently be discharged from the districts now under consideration.

It is evidently possible to collect the sewage of Wigginville and South Lowell by gravity into a main sewer laid in the streets and along the railroad, on the easterly bank of the river, and dispose of it by discharging it into the existing sewer at Rogers Street. No definite studies appear to have yet been made which would serve as a basis for estimating the probable cost of construction of the sewer suggested.

It is also evidently practicable to collect all the sewage of Wigginville and South Lowell at some convenient point not far from the location of the southern division of the Boston & Maine Railroad, and pump it to a disposal area to be located on the westerly side of the railroad. An area suitably located for filter beds can be found in this region, and the soil in parts of this area is apparently well adapted for the purification of sewage by intermittent filtration. It is very probable that the sewage of the higher parts of the territory in question could be conveyed to filter beds in the region suggested by gravity, and in that case it would be necessary to pump only the sewage from the lower levels.

While no estimates have been made of the cost of disposal of the sewage of Wigginville and South Lowell by this plan, it is probable that, judging from the cost of similar works recently constructed elsewhere, the cost of works for collecting and purifying the sewage by this plan would be less than that of conveying the sewage to an outlet at Rogers Street, and results which would be entirely satisfactory from a sanitary point of view could be secured by the adoption of this plan.

In order to prevent a large territory of nearly submerged land from being a menace to the public health, grades should be established for the streets sufficiently high to make it practicable to drain the territory properly. The land should be filled to a grade in general above that of the streets in order that water falling upon it shall flow into the street gutters and the danger of the formation of pools of water which will cause malaria be prevented. The elevation of the bottom of cellars should be fixed by ordinance at heights which will make them capable of proper drainage.

A thorough study should also be made of the best plan of removing the storm water from the district, utilizing the existing water courses, and provision should be made for securing control of such of them as may be necessary for the purpose at the earliest opportunity. Careful estimates should then be made of the cost of constructing sewers for this district, and definite plans of sewerage and sewage disposal prepared.

When you have made further investigations and prepared the necessary plans, the Board will give you further advice as to the sewerage and drainage of these districts, if you so request.

DEC. 22, 1908.

To Mr. GEORGE BOWERS, *City Engineer, Lowell, Mass.*

DEAR SIR: — The State Board of Health received from you on Oct. 14, 1908, the following communication requesting its advice relative to the sewerage of the districts known as Wigginville and South Lowell, situated on the easterly side of the Concord River, in the city of Lowell: —

During the summer I have made additional surveys and estimates for the work on the Wigginville sewers.

In your communication of June 15, 1908, you "recommend that, before a sewerage system is constructed in this district, the streets be raised, where necessary, to a sufficient elevation above the river, in general as much as 5 feet above the level of the freshets, so as to provide adequate drainage at all times, and that a minimum elevation for buildings in this district be prescribed which shall be such as will allow for their proper drainage."

Raising the grade of the streets will make possible another way of disposing of the sewage in Wigginville. That is, by substituting a 36-inch brick sewer for the present pipe sewer in Lawrence Street, but at a lower grade, from the end of the brick sewer, opposite South Whipple Street, to Moore Street; then southerly to Concord River; then under Concord River by a siphon, using 24-inch iron pipe; then changing to 24-inch clay pipe, to Billerica Street. The estimated cost of this work is $34,000, of which amount $20,000 would be used in improving the present system, as the pipe sewer in Lawrence Street is too small and has already given us trouble.

In building this sewer a settling basin can be built to collect the sludge south of the siphon, so that all solid matter will be collected and not discharged into the river.

A sewer laid on the bank of the Concord River from Rogers Street, at the Boston & Maine Railroad crossing, to Billerica Street, to be laid of 24-inch clay pipe, reinforced with concrete where necessary, and an iron pipe under railroad track; estimated cost, $31,300. I submit a plan and profile of the same.

Filter beds, located on land of the Wamesit Power Company, containing two acres, with 24-inch clay pipe running from the bed to the intersection of Easton and Denton streets; estimated cost, $16,000.

Pumping plant, including storage tank and force main, located near the Lowell & Lawrence Railroad, opposite Warnock Street; estimated cost, $14,000.

Sewer 12 inches in diameter from Lawrence Street, at Burton Street, through private land to Carmine Street; thence in Carmine Street to Woburn Street; thence in Woburn Street to Easton Street; thence in Easton Street to Denton Street, a total distance of about 2,250 feet, at a grade of 1 foot in 500 feet; estimated cost, $12,000.

This grade is not satisfactory for 12-inch pipe, but is the best that can be obtained for this sewer. I submit a profile of the same.

Twelve-inch sewer from Lawrence Street, at Burton Street, through private land to Spruce Street; thence in Spruce Street to Woburn Street; thence in Woburn Street to Eugene Street; thence in Eugene Street to Billerica Street; grade 1 foot in 500 feet, estimated cost, $4,800; grade 2 feet in 500 feet, estimated cost, $6,500. A profile of the sewer is submitted.

I have not estimated sewers in Billerica Street and streets running into Billerica Street because the principal cost is in filling the streets.

I submit a plan showing sections of Wigginville and South Lowell which can be drained on to a filter bed by gravity, and sections where the sewage will have to be pumped.

Section A contains 60.79 acres and has 50 houses; section B contains 25.35 acres and has 77 houses; a total of 86.14 acres and 127 houses, from which sewage will have to be pumped.

Sections C, D, E and F can be drained on to a filter bed. Section C contains 11.31 acres and has 54 houses; section D contains 5.07 acres and has 7 houses; section E contains 13.64 acres and has 8 houses; section F contains 87.84 acres and has 36 houses; a total of 117.86 acres and 105 houses.

I submit a plan and profile of Billerica Street, from Lawrence Street to Clifton Street, showing grade of sewers, one running directly between these streets and the other running to the pumping station from the same streets.

I think that the plans and estimates herewith submitted cover the principal points called for in your communication, and I would therefore ask your advice as to the best solution of the problem, under the circumstances.

The application was accompanied by a plan of the districts of Wigginville and South Lowell, and profiles showing the main sewers which would be required to carry into execution the plans of sewage disposal suggested.

The combined area of Wigginville and South Lowell, in which sewerage is now required or is likely to be required before long, is a little more than 200 acres, and the districts include at the present time about 265 dwelling houses, containing an estimated population of 1,600. There are two considerable elevations in these districts, each extending somewhat more than 30 feet above the level of the Concord River. Between these higher areas there is a low area drained by a small tributary of the Concord River, and also a very low area bordering the river itself and but a few feet above its level. In a previous communication the Board has advised the filling of these low areas to such a level as will make it practicable to provide adequate drainage and bring them into a proper sanitary condition, and it is understood that that recommendation is now to be carried out by the city.

It was also recommended in that communication that a thorough study be made to determine the best plan of sewerage and drainage for these areas, and the results of these further studies have now been presented. The investigations show that there are three practicable plans of collecting and disposing of the sewage of the districts in question, which are as follows: —

1. By constructing a sewer along the east side of the river, beginning in Billerica Street near the stone arch bridge of the southern division of the Boston & Maine Railroad, over the Concord River and passing

through Billerica and Lawrence streets to the southerly end of the Lawrence Street bridge, and continuing in that street across the Concord River and along the westerly side of the river to the junction of Lawrence and South Whipple streets, where the sewer would enter one of the principal main sewers of the city, through which the sewage would be conveyed to an outlet into the Concord River not far from the point where that stream joins the Merrimack.

2. By constructing a main sewer, as before, in Billerica and Lawrence streets as far as the easterly end of the Lawrence Street bridge, and then turning to the north along the railroad embankment on the east bank of the river to a connection with the present sewer in Rogers Street.

3. By conveying all of the sewage from the higher levels of the district in question to a filtration area to be located near the east bank of the Concord River about 1,000 feet south of the stone arch bridge already referred to, and purifying it there by intermittent filtration through sand filters, to be constructed of the soil found in the higher land in that locality. The studies show that the sewage of the higher areas in Wigginville and South Lowell can be conveyed to the proposed filtration area by gravity, but that from the low areas will have to be pumped, and it is proposed to collect the sewage from the low areas at a pumping station to be located near the Lawrence branch of the Boston & Maine Railroad, and pump it into the main sewer leading to the filtration area at some convenient point, probably at the corner of Easton and Denton streets.

The estimated cost of the main sewer under the first plan, from its lower end at the corner of South Whipple and Lawrence streets up to Billerica Street, is $34,000. It appears that there is a sewer already in existence in Lawrence Street, from South Whipple Street up to Moore Street, which has become inadequate for the present requirements of the district, and the new sewer would replace the small sewer now in use, which must soon be rebuilt in any case. If the cost of rebuilding the small sewer should be deducted from the above estimate, the cost of conveying the sewage of Wigginville and South Lowell from a point near the junction of Billerica and Lawrence streets to a connection with the main sewer at the corner of Lawrence and South Whipple streets, on the westerly side of the Concord River, would be $14,000.

Under plan No. 2 the estimated cost of constructing the proposed main sewer, from its lower end at Rogers Street, on the east side of the Concord River, up to the point near the junction of Billerica and Lawrence streets, is $31,300.

Under the third plan, which provides for purifying the sewage of

the districts in question, the estimated cost of constructing the main sewers to the proposed filtration area, exclusive of the main sewer in Billerica Street, at the minimum grade available, which would in this case be satisfactory for the purpose, is $4,800, and the cost of the pumping plant, including the storage tank and forcemain, $14,000, making the total cost of main sewers, pumping station, etc., for the low-level district, $18,800. The cost of the main sewer for the high-level district, to convey sewage to the corner of Denton and Easton streets, is estimated at $12,000; and the cost of the main sewer from Denton and Easton streets to the filter beds, including the cost of filter beds, $16,000, making the total estimated cost of works for disposing of the sewage by filtration on land $46,800. To the above should of course be added an amount representing the cost of pumping and of maintenance of the filter beds.

The Board has considered the proposed methods of sewage disposal for Wigginville and South Lowell, and the plans and estimates of cost presented. By either of the first two plans the sewage would be discharged into the present sewerage system of the city of Lowell, and would find an outlet into the Concord River through one of the main sewer outlets of the city located near the western bank of that stream, about a quarter of a mile from its mouth. A large part of the sewage of the western section of the city of Lowell is now discharged into the river at this place, and at times of low flow the river in the neighborhood of this outlet is badly polluted. It is likely that it will eventually be necessary to change this outlet and remove the sewage to some more favorable point of discharge. The additional quantity of sewage that would be discharged at this outlet, under either of the first two plans presented, would not seriously increase the objectionable conditions now existing there or add materially to the cost of improvements when they become necessary, and the conditions affecting this outlet would not, under the circumstances, in the opinion of the Board, make it necessary to reject either of these plans on that ground.

In comparing the cost of disposing of the sewage under the three plans presented, it should be noted that the estimate of disposing of the sewage by intermittent filtration includes the cost of certain sewers which would also be necessary under either of the other plans, and consequently the cost of those sewers should be omitted in comparing the plans presented. For example, a low-level main sewer in Lawrence, Spruce, Woburn and Eugene streets, or in that neighborhood, would have to be built in connection with any plan of sewerage for this territory. The high-level main sewer designed to convey the sewage to the proposed filtration area would be laid in several streets, in which sewers would eventually have

to be constructed, under either of the other plans, so that a part of that estimate also should be omitted in comparing the cost of the filtration scheme with that of the other two plans. Furthermore, there appears to be no necessity for locating the pumping station in the filtration scheme as far north as the neighborhood of the Lowell & Lawrence Railroad. It could probably be located satisfactorily not far from the corner of Billerica and Denton streets, and thus greatly shorten the force main without materially affecting the cost of the sewer which must be laid in Billerica Street, and consequently the cost of a considerable portion of the length of that force main should be eliminated in comparing the filtration scheme with the others.

These allowances would amount to at least from $10,000 to $11,000, and the cost of the filtration scheme reduced by that amount would be about $36,000. Under the filtration scheme, however, it would be necessary to add probably as much as $1,000 per year for maintenance of pumping and filters, though a smaller amount would probably be sufficient in the earlier years. The amount stated represents the income of $20,000 at 5 per cent., and adding that to the cost of works under the filtration scheme, the total cost of the latter would be about $56,000, — an amount considerably in excess of former estimates of the cost of either of the other schemes. It seems likely, on the whole, judging from the information presented as a result of your recent investigations, that either of the plans which provide for discharging the sewage of Wigginville and South Lowell into the main sewerage system of the city, as proposed, would be less expensive than the plan of disposing of the sewage by filtration.

Of the two plans proposed for discharging the sewage into the main sewerage system of the city, plan No. 1, under which the sewage would be conveyed to the main sewer at the junction of Lawrence and South Whipple streets, appears to have a decided advantage in the matter of cost over the plan for conveying the sewage to Rogers Street on the east side of the river, since by the former plan it will be practicable to replace a sewer too small for the district which it is designed to serve.

Having considered the plans and estimates of cost now presented, the Board is of the opinion that the best practicable plan for disposing of the sewage of Wigginville and South Lowell will be to discharge it into the main sewerage system of the city of Lowell, at the corner of Lawrence and South Whipple streets.

Under the plan presented the main sewer from Wigginville and South Lowell to the proposed outlet at the corner of Lawrence and South Whipple streets will pass under the Concord River in the form of an inverted siphon, and a settling tank is suggested to be located at the

southern end of the siphon, for the removal of solid matter therefrom. Since it is decidedly for the best interests of the city to adopt the separate system of sewerage for disposing of the sewage of Wigginville and South Lowell, it is unlikely, if that system is adhered to, that difficulty will be experienced in the operation of the proposed inverted siphon, if, during construction, the sewers are kept free from large objects and other matters which would tend to cause clogging. Under the circumstances it will be best, in the opinion of the Board, to omit the proposed settling tank at the upper end of the siphon near Lawrence Street bridge, and to provide means of flushing, if necessary, by connection with the city water-supply system, whereby the full pressure of the city water mains may be used in flushing the siphon in case deposits should collect therein.

Ludlow.

Nov. 5, 1908.

To the Board of Selectmen of the Town of Ludlow.

Gentlemen: — The State Board of Health received from you on Sept. 29, 1908, an application for advice relative to the sewerage of a small district in the southerly part of Ludlow, located on the northerly bank of the Chicopee River, opposite the village of North Wilbraham, accompanied by a plan showing the location of the proposed sewer and outlet and the buildings likely to be served thereby.

The upper end of the proposed sewer, as shown upon the plan, is to be located at the junction of the highways leading from Wilbraham to Ludlow Center and Three Rivers, respectively, whence its course is to be southwesterly through the highway and across the road leading from Wilbraham to Ludlow Center to a point about half way between the latter highway and the tracks of the Athol Branch of the Boston & Albany Railroad, thence westerly a distance of about 652 feet, approximately parallel with the highway, and finally southerly, passing under the railroad to the Chicopee River.

The sewer is designed primarily to take the sewage from a number of tenement houses on the southerly side of the road from Wilbraham to Ludlow Center, but it is also to receive storm water from two catch basins to be connected at its upper end.

The Board has caused the locality to be examined by one of its engineers and has examined the plan presented. It is not ordinarily desirable to collect storm water and sewage in the same pipes, but in this case there appears to be no serious objection to discharging surface water from the proposed catch basins into the sewer, at least for the present.

In the opinion of the Board the plan is a suitable one for the re-

moval of the storm water and sewage from the districts in question, and the disposal of the small quantity of sewage likely to be collected by this sewer by discharging it directly into the Chicopee River is permissible under the circumstances. In order to avoid danger of nuisance in the neighborhood of the outlet, the Board recommends that the sewer be extended into the river beyond the limit of extreme low water.

MEDFIELD (MEDFIELD INSANE ASYLUM).

SEPT. 3, 1908.

To the Board of Trustees of the Medfield Insane Asylum, EDWARD FRENCH, M.D., *Superintendent.*

GENTLEMEN: — The State Board of Health received from you on July 30 an application for advice as to a proposed system of sewage disposal for the Medfield Insane Asylum, accompanied by plans of the proposed works, which provide for discharging the sewage upon 12 filter beds, having an aggregate area of about 3½ acres, to be located near the Framingham & Mansfield Branch of the New York, New Haven & Hartford Railroad, about a quarter of a mile from Canal Street and half a mile or more southeast of the asylum buildings.

The filters are to be located along one side of a ridge containing gravelly soil, and are to be constructed in part artificially of gravel to be removed from the higher parts of the ridge to the low land adjacent thereto. The plans provide for an underdrain in each filter, the depth of which is not given, but it is understood that the depth of the filtering material is to be at least 5 feet. The filters as shown on the plans presented will range in size from 10,770 square feet to 13,838 square feet, and are to be located on either side of the main sewer at its lower end. Sewage can, however, be diverted from the main sewer before it reaches the filter beds, and used for irrigation, and a considerable quantity of the sewage of the asylum is disposed of in this way at the present time.

The Board has caused the locality to be examined by its engineer and has examined the plans and information presented therewith, and is of the opinion that filter beds of the area proposed, constructed of the coarse sand and gravel found in the locality, will, if properly constructed and maintained, provide adequately for the purification of all of the sewage of the institution at the present time. A portion of the area to be used for filter beds is already used for the disposal of the sewage of the institution, but as the filters were not properly built in the beginning, the distributing system and the underdrains in that area will require reconstruction, and it will also be necessary to clean the beds thoroughly and bring their surfaces to a proper elevation.

The number of underdrains which it is proposed to provide, as shown on the plans presented, is somewhat limited for the proper drainage of the filters in view of the shape of the beds, and the Board recommends that two underdrains be constructed in each filter at proper distances apart. It is also desirable to provide a larger number of outlets for the sewage and at least two outlets should be provided upon each of the filters.

At the present time the greater part of the sewage from the institution passes through a settling and flush tank located near the buildings, the sludge from which is discharged upon sludge beds near by. A very offensive odor arises from these sludge beds, which is noticeable on the driveways and on the highway in the neighborhood of the buildings, and the disposal of sludge in this locality had best be discontinued. It may be practicable to discharge the sludge upon beds located south of Canal Street, and if so it would be best to divert the sludge to that locality. It is not essential, however, to separate solid matter from the sewage in this case before applying it to the filter beds, and since, with two outlets upon each bed, the filters can be dosed with the ordinary run of sewage in from one to two hours, the settling and flush tanks can be dispensed with without interfering seriously with the efficient operation of the works. It is advisable, however, in case the use of the settling and flush tanks is discontinued, to screen the sewage, which contains many large objects, before discharging it into the main sewer.

The plans presented, with the modifications suggested, will, in the opinion of the Board, provide a satisfactory method for disposing of the sewage of the asylum. It is very important, however, that the works be constructed under careful engineering supervision, and it is especially important that they be properly maintained and operated after they are completed. The sewage should be discharged upon the filter beds intermittently, and each bed allowed to dry between each application of sewage. All of the beds should be used each day so far as practicable, and care taken to distribute the sewage equally to all parts of the area. The surfaces of the beds should be cleaned when necessary for the removal of matter which may accumulate thereon, and it will be best to clean one or two beds at a time, so that it may not be necessary to apply sewage in excessive doses to the remainder of the area. It will also be practicable to continue to use the sewage for irrigation on the areas where it is now used for that purpose, but care must be taken not to apply larger quantities of sewage to these areas than the ground is capable of absorbing.

MILFORD AND HOPEDALE.

OCT. 23, 1908.

To Messrs. FRANK P. DILLON, LOUIS P. PRATT and FRED E. WOOD, *Board of Sewer Commissioners of the Town of Milford*, and Messrs. C. E. PIERCE, C. H. DRAPER and GEO. A. DRAPER, *Road Commissioners of the Town of Hopedale.*

GENTLEMEN: — The State Board of Health has examined the agreement between your boards relative to the connection of certain territory in the town of Hopedale with the sewerage system of the town of Milford, and has also examined the plan of the proposed connection submitted therewith; and having caused the locality to be examined, hereby approves the agreement and plan as provided by chapter 281 of the Acts of the year 1908.

MONSON.

SEPT. 3, 1908.

To the Committee on Sewerage of the Town of Monson, Mr. FREELON Q. BALL, *Chairman.*

GENTLEMEN: — The State Board of Health received from you on August 29 the following communication for advice relative to the disposal of sewage of the village of Monson: —

The committee chosen by the town of Monson to consider the matter of a system of sewerage for the town desire to know if it would meet the approval of your Honorable Board if the sewage were turned into the stream running through the town, known as Chicopee Brook, at a point below the former village of North Monson, said point being below any present or prospective mill privileges and about 2½ miles above the junction of said stream with the Quaboag River.

In response to this application the Board has caused the locality to be examined by its engineer, and has examined the information available as to conditions in the valley of Chicopee Brook and the probable effect of the discharge of the sewage of Monson below North Monson.

The records of the census do not show the present population of the village, but judging from the number of dwelling houses shown upon the atlases of the town, there is a population of about 2,000 in the portions of the town in which sewers would be likely to be constructed, but the population using the sewers would probably be less for a few years in the beginning than the number above indicated.

Below the proposed point of discharge of the sewage of Monson Chicopee Brook flows through a sparsely settled valley and there are no dwelling houses within the immediate vicinity of the stream until

it joins the Quaboag River, a condition which is favorable to the use of the stream as a place of sewage disposal. On the other hand, the watershed of the brook is so limited that it is evident from experience with other streams that if all of the sewage of the main village of Monson should be discharged continuously at the point proposed, a very serious nuisance would result in the drier portion of the year.

The stream is already polluted to a considerable extent by sewage and manufacturing wastes from the village, as shown by chemical analyses, and considering the circumstances the Board is of the opinion that it is not advisable for the town to attempt to use Chicopee Brook below North Monson as a permanent outlet for its sewage. It is probable, in the opinion of the Board, that it will be permissible to discharge the sewage from the village into the stream temporarily during the construction of the works, and possibly to continue the discharge for a period of two or perhaps three years after the works are first put in operation. It is improbable that the discharge could be allowed to continue for a longer time than three years without creating objectionable conditions.

The best plan of disposing of the sewage of the village will probably be to purify it on filter beds of sand or gravel, and there appears to be land suitable for this purpose in the valley of the brook below North Monson.

The Board recommends that, in the preparation of plans for sewerage works, you investigate carefully the best plan of disposing of the sewage, and select a location for the works, so that a means for the proper disposal of the sewage can be provided either when the works are built or whenever thereafter the purification of the sewage becomes necessary.

MONSON (MASSACHUSETTS HOSPITAL FOR EPILEPTICS).

Nov. 12, 1908.

To the Trustees of the Massachusetts Hospital for Epileptics, Palmer, Mass., EVERETT FLOOD, M.D., *Superintendent.*

GENTLEMEN: — The State Board of Health has considered your application for advice with reference to the disposal of the sewage of a group of buildings, known as the children's colony, which you propose to convey a distance of about 3,000 feet to the small filter beds in the rear of the Brick House, so called, near the road from Palmer to Monson, and in response to this application has caused the locality to be examined by one of its engineers.

The filter beds in question are apparently composed of soil well suited to the purposes of sewage purification, but it is unlikely that they could

care for a much greater quantity of sewage than is now discharged upon them, and their location is such — being close to the road from Palmer to Monson and in the immediate neighborhood of a number of dwelling houses — that it is not advisable, in the opinion of the Board, to enlarge that area or increase the quantity of sewage discharged upon it.

It appears that the sewage from the main buildings is now disposed of during part of the year by irrigation on a hillside north of the hospital buildings, and in winter upon filter beds constructed on the easterly slope of the hill near the Quaboag River. There appears to be no serious objection to the use of sewage for irrigation upon the hillside, as in the past, provided sufficient care is exercised to prevent danger of its flowing over the ground to the stream without purification. It is evident, however, that the filter beds now used are inadequate for the disposal of the sewage of the main buildings in the winter season, and it is unlikely that they would care satisfactorily for all the sewage which it might be desirable to discharge upon them during wet weather in other seasons of the year. It is practicable to enlarge this filtration area without much difficulty so as to care for all of the sewage of the institution, and there appears to be no reason to doubt that the sewage from the new children's colony can be conveyed to that area by gravity without serious difficulty. Moreover, it is likely to be less expensive to convey the sewage of the new children's colony to that area and dispose of it there than to the filtration area near the Brick House.

After consideration of the circumstances it appears to the Board that the best practicable plan of disposing of the sewage both from the children's colony and the other buildings of the institution will be to discharge it upon filter beds located in the neighborhood of those now in use northeast of the hospital buildings, enlarging that area as much as may be necessary upon the side away from the buildings to make it adequate for the purification of all of the sewage which may be discharged there.

The Board recommends that you have investigations made and plans prepared by an engineer of experience in such matters for the construction of an adequate area of filter beds for the disposal of all of the sewage of the institution that it is practicable to convey to the neighborhood of the present main sewage-disposal area by gravity, and when such a plan has been prepared the Board will, upon application, give you further advice as to the disposal of the sewage of the institution, including the new buildings.

North Andover.

Jan. 20, 1908.

To the Board of Public Works, North Andover, Mass., Messrs. Nathaniel Stevens, Andrew Reeves and William Somerville.

Gentlemen: — The State Board of Health received from you on Dec. 4, 1907, an application for its advice relative to a proposed system of sewerage for the town of North Andover in which you present the following outlines of your proposed plans: —

> It is proposed to add to the drainage area served by the present outlet into the Merrimack River that area designated as the east side drainage area, and to construct a new outlet into the Merrimack River, about 1,300 feet west of the present outlet, to drain that district designated as the west side drainage area.

The application is accompanied by a plan of the proposed sewers, submitted by your engineer, Mr. E. W. Bowditch of Boston, and profiles of the proposed main sewers have also been submitted.

The plans in general provide for enlarging the east side drainage area, so called, in which a system of sewers has already been constructed, by extending the sewers to parts of the district not served by the present system, retaining the present outlet of this system, which now discharges into Cochickewick Brook about 100 feet from its confluence with the Merrimack River. The proposed west side system will serve the northwesterly portion of the town adjacent to the city of Lawrence, in which only a short length of sewer has thus far been constructed. The new west side system will intercept the outlet of the present sewer in that district which now discharges into the Shawsheen River near the bridge just above its mouth, and convey all of the sewage to a new outlet into the Merrimack River about half way between the mouth of the Shawsheen River and Cochickewick Brook.

The Board has caused the locality to be examined by one of its engineers and has examined the plans and information presented therewith.

The present system of sewers was apparently designed to receive sewage only, but there are indications that storm water or ground drainage is admitted to them in considerable quantity. The records of these sewers do not show definitely the number or character of the connections therewith. It is understood that the system which you now propose to construct is to be a separate system, and that storm water, and, so far as practicable, ground drainage are to be excluded therefrom, though this is not stated in the application nor upon the plans presented.

If storm water, and, so far as practicable, ground drainage are kept

out of the sewers the proposed main sewers, as shown upon the plans, should be of sufficient size to remove without difficulty all of the sewage of the districts tributary to them, allowing for a large increase in the population of the town.

The present outlet of the easterly system into Cochickewick Brook is located close to the bank of the brook within about 100 feet of the Merrimack River. While there is no population at the present time in the immediate vicinity of the brook, the outlet is not a satisfactory one, and, with the increased quantity of sewage which it is proposed to discharge there, objectionable conditions are likely to result. The proposed new outlet half way between the mouth of the Shawsheen River and Cochickewick Brook extends only to about 10 feet from the bank of the river, according to the plan submitted, and there would be considerable danger here also of the fouling of the shores by sewage.

The Board would recommend that the outlet at Cochickewick Brook be extended to the middle of the stream at its outlet into the Merrimack River. The proposed new outlet between the Shawsheen River and Cochickewick Brook should be extended a distance of 50 feet from the shore at ordinary height of water, to prevent matters from the sewage being cast upon the shore in its neighborhood, and allow a stream of clear water between the sewage and the shore. Otherwise the bank of the river between this outlet and Cochickewick Brook will be seriously fouled by sewage.

The Board is of the opinion that, with the changes suggested in the outlets of the sewers, the system will provide satisfactorily for the disposal of the sewage of the town until the population becomes much larger than at the present time.

North Attleborough.

Oct. 1, 1908.

To the Sewerage Committee of the Town of North Attleborough, **Mr. G. K. Webster,** *Chairman.*

Gentlemen: — The State Board of Health received from you on June 24, 1908, through your engineer, an application for the consideration of plans of sewerage and sewage disposal for the town of North Attleborough, which were submitted with the application.

The plans provide for a system of pipe sewers to collect the sewage of the town into a main sewer in the valley of the Ten Mile River, in which it is to be conveyed to a filtration area to be located between the Attleborough Branch Railroad and the Ten Mile River, within 1,500 feet of the boundary line between Attleborough and North Attleborough, where it is to be purified by intermittent filtration and the effluent dis-

charged into the Ten Mile River. It appears that certain thickly settled areas in the southerly part of the town are situated at such a low level, as compared with the elevation of the filtration area, that it would be impracticable to discharge the sewage from them into the main sewer by gravity, and the plans provide for collecting the sewage of the southerly portion of the town south of the neighborhood of Mount Hope Street at a pumping station to be located between Freeman Street and North Avenue, about 800 feet south of Commonwealth Avenue, from which it is to be pumped into the main sewer in North Avenue.

It has also been found necessary to construct the main sewer at two places in the form of an inverted siphon for a length of a little over 700 feet in the neighborhood of Mount Hope Street, and for a length of about 1,634 feet between North Avenue and the filtration area; and the capacities of these siphons have been made much smaller than that of the main sewer in order to secure a more rapid velocity through them and prevent the formation of deposits.

The proposed filtration area is located in the northerly part of the town of Attleborough within the limits designated by chapter 448 of the Acts of the year 1908, and a considerable number of test pits has been dug in various parts of the area to determine the character of the soil. The plans provide for the construction on this area of 2 settling tanks having an aggregate capacity of 100,000 gallons, a dosing tank having a capacity of approximately 20,000 gallons, 15 filter beds having an aggregate area of about 7 acres and a sludge bed having an area of a little over one-third of an acre. Three underdrains, about 55 feet apart, are provided in each filter.

The Board has caused the locality to be examined by its engineer and has examined the plans and the report presented therewith.

The information furnished by your committee and your engineer indicates that there are no available areas of land within the limits of the town of North Attleborough containing soil suited to the purification of sewage by intermittent filtration upon which the sewage of the town can be discharged by gravity, and the area selected within the limits of the neighboring town of Attleborough appears to be the best one available for the purpose. An examination of the soil in test pits dug upon that area shows that in most places it is coarse and porous and well suited for the purification of sewage. In other places the soil consists largely of hardpan or other objectionable material, but it is evidently practicable, judging from the tests, to construct at this place a sufficent area of filter beds for the purification of all of the sewage of the town, and additional areas can be made available in the future in this neighborhood if necessary.

If the sewers are well built, and surface water and ground drainage excluded so far as practicable, the area of filters which it is proposed to provide in the beginning is likely to be sufficient for the requirements of the town for several years. With a settling tank of the size proposed it will be important in the beginning, and until the sewers have come into general use, to use only one compartment at a time and clean the tank frequently to avoid putrefaction of the sewage and objectionable results therefrom.

The line of the proposed main sewer contains several sharp angles and is less direct, than desirable. It should be straightened if practicable without increasing materially the cost of the works. The sizes of the sewers shown upon the plans are ample, and the capacities of the inverted siphons are likely to be sufficient in the beginning. The capacity of the longer siphon near the filter beds may be reached soon after the works have come into general use, and it is desirable to lay a somewhat larger pipe for this siphon in the beginning. The Board also recommends that, if possible, provision be made for flushing the siphons with water under pressure from the water supply system of the town.

It is very desirable that underdrains be laid wherever practicable beneath the main sewers where the latter are below the level of the ground water, as advised by your engineer, and it is also important, in constructing the system, that the sewers and house connections be carefully laid, so as to avoid, so far as possible, the entrance of surface water and ground drainage and consequent unnecessary expense in the maintenance of the system and disposal of the sewage.

In the opinion of the Board the plans presented, with the modifications suggested, will provide satisfactorily for the disposal of sewage of the town of North Attleborough.

RUTLAND (STATE SANATORIUM).

AUG. 6, 1908.

To the Board of Trustees of the Rutland State Sanatorium, FREDERICK L. HILLS, M.D., *Superintendent.*

GENTLEMEN: — The State Board of Health received from you on July 13, 1908, the following application for advice with reference to enlarging and improving the system of sewage disposal of the State Sanatorium at Rutland: —

I am sending you, under separate cover, a copy of blueprint showing additions which we propose making to the present filter beds connected with the sanatorium. It is proposed to enlarge these beds as shown on the print, and in addition to make repairs on the pipe line where a considerable amount of surface water is now being taken in. . . .

The plan submitted with the application shows two additional filter beds adjacent to those now in use. These proposed filters are to have an aggregate area of 12,000 square feet and are to be underdrained into the adjacent stream. With these additions the total area of filters would amount to about 1.4 acres.

No accurate measurements are available to show the quantity of sewage discharged upon the filter beds, but the quantity of water used at the institution is now metered, and this quantity, which amounts to apparently between 30,000 and 40,000 gallons per day, is probably a fair index in this case of the quantity of sewage produced. The amount of sewage reaching the filtration area, however, is greatly increased by the leakage of water into the main sewer where it crosses a stretch of marsh land, so that the quantity of sewage which it is necessary to purify is much greater than would be the case if the sewer were properly constructed. By rebuilding the portions of the sewer in which the excessive leakage now occurs, the quantity of sewage to be treated at the filtration area in the future will probably be materially reduced.

The Board has caused the locality to be examined by one of its engineers and has examined the plans presented. It appears that the area of filter beds now available for the disposal of sewage at this institution is about 1.1 acres, and that while the soil in a portion of the area is somewhat fine, the greater portion contains soil well suited for the purification of sewage by intermittent filtration.

It is evident that the filter beds have been greatly overtaxed at times, partly, no doubt, on account of the excessive quantity of sewage discharged upon them during a portion of the year, but principally on account of the fact that they have not received the necessary care to keep them in proper condition for efficient work. In consequence of these conditions untreated sewage has been discharged at times directly into the adjacent stream.

It is impracticable to determine, under the existing conditions, whether if the leakage into the main sewer were prevented and the beds kept in proper condition a larger area of filters would be necessary or not, but it is very important that provision should be made as soon as practicable to prevent the further discharge of unpurified sewage into local waters, and the Board would recommend as the first step in improving your system of sewage disposal the relaying of such portions of the main sewer as now admit considerable quantities of ground water, so as to reduce as much as practicable the quantity of sewage requiring purification. The Board would further recommend that the filter beds be thoroughly cleaned and that they receive the necessary attention hereafter to keep their surfaces in a proper condition, and that the sewage

be applied to them intermittently, using practically all portions of the area each day. When the work upon the main sewer has been completed and the filter beds brought into a proper condition the Board will, upon request, make a further examination and advise you as to the necessity for enlarging the filtration area and the plan presented therefor.

The Board would again call attention to the necessity for proper care of the settling and flush tanks, which appear to have been neglected for several years. There would be certain advantages in changing the location of these tanks, concerning which you were advised in a communication dated Sept. 3, 1903, a copy of which is enclosed.

Stoughton (Stoughton Mills).

June 4, 1908.

To the Stoughton Mills, Midway Street, Boston, Mr. Reuben Broomfield, *President.*

Gentlemen: — The State Board of Health received from you on May 18, 1908, an application for advice with reference to a proposed plan for the disposal of the wastes from your mills at West Stoughton in order to prevent the further pollution of the Neponset River therefrom.

The plan provides for the construction of a settling tank, having a capacity of a little less than 16,000 gallons, to provide for the sedimentation of the wastes; for a sludge bed to receive the sludge from the tank; and for 2 filter beds, having an aggregate area of a little less than .40 of an acre, to be constructed of gravel about 30 inches in depth and underdrained into the river.

It appears, from such information as is available to the Board, that the quantity of wastes discharged from this factory does not exceed 70,000 gallons per day, consisting chiefly of water used in the washing of rags and a comparatively small quantity of wastes from dyeing. Much acid is used in the processes carried on in the factory, which evidently affects the effluent and will require neutralization, the plan for accomplishing which is outlined in your application as follows: —

> The wastes produced at this factory are frequently very acid, but at other times large quantities of alkali are used, and it is expected that by mixing the wastes in the settling tank the acid will be largely neutralized. If this is not the case, the required alkali can be added to the wastes as they are discharged into the settling tank.

The Board has caused the locality to be examined by its engineer and has considered the plan presented and the results of experiments upon the purification of these wastes.

The tests of the acidity of the wastes from the washing of rags in this mill at various times show that from 250 to 1,200 pounds of lime are required to neutralize the acid in 1,000,000 gallons, or from about 20 to about 100 pounds for the volume of wastes discharged daily from this mill. By mixing the alkaline wastes which are discharged from the mill with the other wastes, as proposed, the quantity of alkali required to neturalize the acid will be reduced.

The wastes from the mill contain much organic matter, a large proportion of which is in suspension, and it is doubtless practicable to remove a large proportion of the objectionable matters by sedimentation. The proposed settling tank appears to be large enough to secure all of the benefit practicable from sedimentation while the quantity of wastes is no larger than indicated. It is evidently impracticable to construct a sludge bed at a sufficiently low level to receive the wastes from this tank, and it will consequently be necessary to pump the sludge from the tanks whenever they require cleaning. It is important that the tanks be cleaned frequently in order to secure the best results.

The area of filter beds which it is proposed to provide is too limited to properly purify the sewage, and the Board would recommend that the area of filter beds be made as much as twice as great as proposed in the plan presented. With the larger area of filter beds suggested, and with proper care in neutralizing the wastes and in cleaning the settling tank, the filters will probably purify satisfactorily all of the wastes discharged from the mill if the quantity is no greater than indicated above.

OCT. 1, 1908.

To the Stoughton Mills, Midway Street, Boston, Mass., Mr. REUBEN BROOMFIELD, *President.*

GENTLEMEN: — The State Board of Health received from you, through your engineer, on August 18, the following request for a further examination of the processes carried on in your mill at West Stoughton: —

The Stoughton Mills at Stoughton have within the past year, or since the investigations of the manufacturing wastes were made by the State Board of Health, made very material changes in the processes carried on at the factory which I am convinced will change the character of the wastes. I am about to prepare plans for the disposal of the wastes, and in accordance with your recent advice, but it seems to me that it is essential, before building works, to determine what effect the changes in the processes will have upon the wastes. I assume that you will be glad to have the plant re-examined, and I shall be pleased to do anything in my power to assist you.

In accordance with this request the Board has caused a further examination to be made of the processes carried on in your mill and sam-

ples of the effluent therefrom to be analyzed. The results show that there has been no material change, either in the quantity or character of the wastes, since the earlier examinations were made, on which the advice of the Board of June 4 was based. The wastes, while occasionally found to be alkaline, are usually acid, and can best be purified by intermittent filtration after sedimentation and the application of sufficient lime or alkali to neutralize the acid present. The Board sees no reason, from the results of the recent examination, for modifying the advice given in its communication of June 4, 1908.

Taunton (Taunton Insane Hospital).

Feb. 6, 1908.

To the Board of Trustees of the Taunton Insane Hospital.

Gentlemen: — In response to your request for an examination of the sewage-disposal system of the Taunton Insane Hospital, and advice regarding the best method of disposal, the Board has caused the present sewerage system to be examined by one of its engineers and has considered the methods available for the proper disposal of the sewage of this institution.

At the present time all of the sewage of the insane hospital is discharged into Mill River, part of it directly and part of it after passing through a settling tank. This method of disposal is a very objectionable one from a sanitary point of view. The city of Taunton has expended a large sum of money to remove the sewage of the city from Mill River, and it is important that the sewage of the hospital be removed therefrom as soon as practicable. Two methods of disposal are possible, one by purifying the sewage upon the grounds of the institution and the other by discharging it into the sewers of the city of Taunton.

An area of several acres — probably from 3 to 4 acres — would be required for the proper disposal of the sewage of the institution, and it is undesirable, in the opinion of the Board, to attempt to purify the sewage upon your own grounds, which are situated in a thickly populated portion of the city.

The best practicable plan of disposal for the sewage of the institution is to discharge it into the sewers of the city of Taunton. It is impracticable for the Board, with the information now available, to advise you at what point or points it will be best to make connection with the Taunton sewerage system, and a proper determination of this question will require a further study, with the aid of surveys. It will probably be necessary to pass the sewage through tanks in order to remove from it objects which might obstruct the flow in the sewers, and provision should be made for cleaning out the tanks from time to time and for the proper disposal of the sludge.

The Board would recommend that you cause a further investigation to be made, with the assistance of an engineer of experience in matters relating to sewerage, to determine the best plan for disposing of the sewage of this institution in connection with the Taunton sewerage system. When a plan has been prepared the Board will give you further advice in the matter if you so request.

DEC. 3, 1908.

To the Board of Trustees of the Taunton Insane Hospital, Dr. ARTHUR V. GOSS, *Superintendent.*

GENTLEMEN: — The State Board of Health received from you on Oct. 30, 1908, the following application for advice relative to proposed plans for disposing of the sewage of the Taunton Insane Hospital: —

The trustees of the Taunton Insane Hospital have had the question of the disposal of their sewerage investigated, according to your recommendation in your communication of Feb. 6, 1908, and submit for your consideration plans for the connection of the sewerage system of the Taunton Insane Hospital with the sewerage system of the city of Taunton. They direct me to state that their preference is for line A.

The application is accompanied by plans showing two methods by which the sewage of the hospital can be collected and disposed of in connection with the sewerage system of the city of Taunton. Both of these plans provide for the construction of a long main sewer to be laid from near the northerly end of the hospital grounds to a connection with the Taunton sewers at the corner of Hodges Avenue and Morton Street, just outside the main entrance.

By the first of these plans (known as line A) the sewer would be laid on a grade of .53 per cent. and would collect the sewage from all of the buildings of the institution, with the exception of a cottage used for the accommodation of a limited number of patients near the extreme northerly end of the grounds.

By the second plan the sewer would be laid in or near the same location but on a flatter grade and at a greater depth, but would provide for the removal of the sewage of all of the buildings on the hospital grounds. By the latter plan (known as line B) the cost of constructing the sewer would be somewhat greater than by line A, but if line A should be adopted it would be necessary either to move the cottage near the northerly end of the grounds to higher land, or to pump the sewage into the main sewer or provide other means for its disposal.

The Board has caused the locality to be examined by its engineer and has considered the plans presented and other possible methods of disposing of the sewage of the institution, and is of the opinion that the

best plan, all things considered, is to construct a sewer on line B at a sufficient depth to provide for the removal of the sewage of all of the present buildings of the institution, and thus at the same time make better provision for future buildings on these grounds than is made by any other plan; and the Board recommends the adoption of that plan for the disposal of the sewage of the Taunton Insane Hospital.

Templeton (Templeton Inn).

Sept. 11, 1908.

To Mr. Percival Blodgett, *Templeton Inn, Templeton, Mass.*

Dear Sir: — The State Board of Health received from you on June 16, 1908, through your engineer, plans and a description of a proposed system of sewage disposal for the Templeton Inn, and has caused the locality to be examined by one of its engineers.

It appears that the quantity of sewage to be disposed of amounts at times of maximum flow to about 8,000 gallons per day, and that complaint has been made of the present method of disposal, by which the sewage is discharged along a hillside southwest of the inn.

The plans submitted provide for the construction of 6 gravel filters, to be located near the area now used for sewage disposal and about 250 feet southeast of the highway leading from Templeton to Phillipston. As the soil at this location is not suitable for the purification of sewage, it would be necessary to haul all of the filtering material from a considerable distance. An examination of the region shows that there is another area, about 1,000 feet farther south and quite remote from dwelling houses, to which the sewage of the inn could be conveyed by gravity, and the soil of which appears to be suitable for the purification of sewage by intermittent filtration. A larger area could be made available in this locality than at the place originally proposed, and while the length of pipe necessary would be greater, it is probable that the cost of the works at the more remote area would be less than at the locality originally proposed.

Considering the circumstances the Board recommends that you have an investigation made with a view to the disposal of the sewage upon the area indicated, about 1,000 feet south of the area proposed in the plan presented. When the plans of the new disposal area have been prepared, the Board will upon application give you further advice concerning the disposal of the sewage.

TEWKSBURY (STATE HOSPITAL).

SEPT. 3, 1908.

To the Board of Trustees of the State Hospital, Tewksbury, Mass., DR. JOHN H. NICHOLS, *Superintendent.*

GENTLEMEN: — Complaint having been made to this Board that Strongwater Brook and the Shawsheen River are being polluted by sewage discharged from the Tewksbury Almshouse, the Board has caused the locality to be examined by its engineer and a sample of the water from the brook to be analyzed.

The results of the examination show that sewage is at times discharged upon the ground near the present filtration area, where it forms a pool, from which it finds its way into Strongwater Brook. As a result of this method of disposing of sewage the conditions about the filtration area are very offensive, and analysis shows that the water of Strongwater Brook is considerably polluted.

It appears from the information available to the Board that the institution contains at the present time a population, including employees, of about 2,100 persons, and that the quantity of water used is about 250,000 gallons per day. The quantity of sewage discharged from the hospital has not been measured and its amount is not definitely known, but it probably does not differ greatly from the quantity of water used, and is evidently considerably greater than the present filtration area is capable of purifying at all times.

In the opinion of the Board the existing conditions are very objectionable, and the Board recommends that the filtration area be enlarged to a sufficient size to provide adequately for the purification of all of the sewage of the institution at all times. It is probable that an area of about 4 acres will be required for that purpose, but in order to determine definitely the area necessary, it will be best to measure the flow of sewage before making plans for the construction of additional works. The Board recommends that before constructing further works for the purification of the sewage you have plans prepared by an engineer of experience in the design and construction of such works, and when the plans have been prepared the Board will advise you concerning them if you so request.

DEC. 3, 1908.

To the Board of Trustees of the Tewksbury State Hospital, DR. JOHN H. NICHOLS, *Superintendent.*

GENTLEMEN: — The State Board of Health received from you on Nov. 25, 1908, an application for advice as to a proposed plan for the enlargement of the filtration area for the disposal of the sewage of the hospital. The application is accompanied by a plan of the filtration

area showing the present filter beds and the proposed additions. The plan provides for the construction of 7 additional filter beds, 2 of which will adjoin the present filters on the west and the other 5 on the east and south, the additional filter beds having an aggregate area of 1.5 acres, bringing the total area of filters up to about 2.9 acres. The proposed filters are to have a depth of from 5 to 6 feet of filtering material, and are to be underdrained by lines of 4-inch tile pipe laid 22.5 feet apart in the new beds in the easterly part of the area and 24 feet apart in the beds in the southwesterly portion. The soil in the vicinity of the filtration area is in places very fine and unsuited to the purification of sewage by intermittent filtration, but it appears to be practicable to obtain an ample quantity of coarse sand or fine gravel suitable for the construction of the filters.

The Board has caused the locality to be examined by one of its engineers and has examined the plans presented. The Board is of the opinion that the proposed filters, if constructed in accordance with the plans presented, using sand or gravel suited to the purpose, and properly operated, will be capable of purifying a large part of the sewage which cannot be treated upon the limited area now available, and the Board recommends that the proposed works be constructed as soon as practicable.

The area of filter beds available for the disposal of the sewage of the institution after the additions now proposed have been made will still be inadequate for the purification of all of the sewage of the institution, but it is understood that you desire to begin upon the construction of these beds at once, and that further additions will be made as soon as practicable, plans for which will be presented when the further studies have been completed.

WAKEFIELD (HEYWOOD BROTHERS & WAKEFIELD COMPANY).

MAY 7, 1908.

To the Board of Health of the Town of Wakefield.

GENTLEMEN: — The attention of the State Board of Health has been called to the method of disposal of the sewage from the premises of the Heywood Brothers & Wakefield Company's works in Wakefield, and the Board has caused the locality to be examined by one of its engineers.

The results of the examination show that the sewage from about 800 operatives in this factory is discharged directly into a tributary of the Saugus River, which is very badly polluted thereby. The offensive condition of this stream is a menace to the health of those living in the valley below, and the Board would advise that you take action as soon as practicable to prevent this nuisance.

The factory buildings are situated at too low a level to make it practicable to discharge the sewage by gravity into the present sewerage system of the town. The plan for the sewerage of the valley in which this factory is situated provides for collecting it at a point below the factory and pumping it into the main sewerage system of the town. If sewerage is necessary in other parts of the low-level district it would probably be best to install this low-level system without delay. If, however, there is little need for sewerage in that district at the present time, except for the disposal of the sewage from the factory, it would probably be best that the factory sewage be pumped temporarily into one of the existing sewers of the town of sufficient capacity for the purpose.

WALPOLE (LEWIS MANUFACTURING COMPANY).

DEC. 3, 1908.

To Mr. H. P. KENDALL, *Treasurer, Lewis Manufacturing Company, Walpole, Mass.*

DEAR SIR: — The State Board of Health received from you on Sept. 23, 1908, an application for advice as to the disposal of manufacturing wastes from the works of the Lewis Manufacturing Company in Walpole, accompanied by a report and plan, proposed by your engineer, showing the method by which it is proposed to treat the wastes before discharging them into the Neponset River; and in response to that application the Board has caused the locality to be examined and has examined the plans presented and the results of experiments on the disposal of these wastes.

The results of the examinations of the wastes from the various operations carried on in the mill show that the total quantity resulting from the different processes aggregates about 50,000 gallons per day, of which the most objectionable appear on analysis to be the water in which the stock has been boiled with ammonium hydrate, the water in which the stock is boiled a second time with soap and the water in which the stock is washed after the first boiling, these wastes amounting in all to a little over 15,000 gallons per day.

It is probable that these wastes could be treated satisfactorily, after sedimentation, upon the filters proposed by your engineer, which, according to the plan presented, would have an aggregate area of about 6,600 square feet, provided the filters were properly constructed and maintained with the necessary care. All of the wastes of the mill could probably be treated successfully, provided their quantity and quality are such as shown by the recent examinations, on filter beds having an area of about half an acre, but the results of the investigation show that, while all of the waters discharged from the mill are polluted in a greater or less degree, some of them were not found to be so badly

polluted that they would be likely to require purification at the present time.

It is important, however, in the opinion of the Board, to prepare a larger area of filters in order that some of the other wastes, which are considerably polluted, such as dye wastes and some of the wastes from washing, can be purified in the beginning, and it appears from the report of your engineer that, in addition to the 6,600 square feet of filter beds shown upon the plan, other filters can readily be built, which would enlarge the area to nearly 12,000 square feet.

The Board recommends that an area of filter beds, amounting to at least 12,000 square feet, be built in the beginning, and provision made, so far as practicable, in constructing the works, to allow for the enlargement of the filtration area in case it should become necessary to treat other wastes or to provide for an increase in the amounts of objectionable wastes discharged from the mill beyond those found at the time the examinations herein referred to were made. Sedimentation tanks of the capacity proposed by your engineer will, if properly designed and operated, be sufficient for present needs.

WALPOLE (F. W. BIRD & SON).

APRIL 2, 1908.

To Messrs. F. W. BIRD & SON, *East Walpole, Mass.*

GENTLEMEN: — The State Board of Health received from you, through your engineer, on Feb. 12, 1908, plans of proposed works for purifying the liquid manufacturing wastes discharged from your paper mill at East Walpole, accompanied by reports of your engineer and consulting engineer relative thereto.

The report of your engineer states that a new mill is being built in another State to which all the felt paper manufacture is now to be removed, and that two of the five paper machines will be transferred to the new mill before the beginning of the coming summer. Of the three remaining machines, two are used in the manufacture of box and roofing papers, the stock for which is not washed, so that only the stock for one machine will be washed at this mill after the completion of the new mill and the changes incident thereto. It is stated, however, that it is possible that one new machine may be added, making four in all.

It is estimated by your engineer that the aggregate discharge from the three machines which will remain permanently at this mill is about 2,000,000 gallons per twenty-four hours, and that if another machine should be added the quantity might be from 2,500,000 to 2,800,000 gallons per day from all four machines. From 300,000 to 400,000

gallons of machine wastes, however, will be used over again in the process of beating the stock in the beating machines, so that the quantity of machine wastes to be disposed of after the changes now contemplated are made will be, according to the estimates of your engineer, from 1,600,000 gallons to 2,800,000 gallons per day, the uncertainty being due, first, to the possibility of the addition of another machine, and, second, to the use of a part of the machine wastes in the process of beating stock.

The waste from the paper machines constitutes the principal part of the wastes to be disposed of from your mill. The method of disposal proposed for this waste is, after passing it through save-alls for the recovery of stock, to discharge it into a settling tank 190 feet long and 35 feet wide, to contain a depth of 14 feet of water, which will be divided into four compartments having an aggregate capacity of about 690,000 gallons. This tank will provide for a sedimentation of from six to ten hours when all the compartments are in use. It is proposed to allow the supernatant liquid, after passing through the tank, to discharge directly into the river without further treatment. When the compartments of the tank require cleaning it is proposed to draw off the liquid from one compartment at a time as low as possible without disturbing the sediment and then to pump the sludge to sludge presses, to be located over the first compartment of the tank, the pressed sludge to be dumped at some convenient place and the water pressed therefrom to be discharged upon sludge beds shown upon the plan east of Washington Street.

It is estimated by your engineer that the waste liquid from the washing of stock will amount to about 300,000 gallons per day after the changes now proposed have been made. The plan for purifying this waste provides for conveying it by gravity through a 12-inch pipe to a sedimentation basin, to be located just north of the railroad on land south of the Hollingsworth & Vose mill and about 3,800 feet from the machine waste tank already mentioned. The washer waste, after passing through this tank, is to be applied to an area of about 1.4 acres of cinder filter beds 3 feet in depth, to be constructed along the bank of the mill pond, the effluent to discharge into the pond. Three sludge beds, having an aggregate area of 12,760 square feet, designed to receive the sludge from the settling tank, are shown upon the plans submitted.

The waste from the boiling of stock has been estimated by engineers from this office to amount to about 10,000 gallons per day, but, according to estimates of your engineer, will amount in future to 1,800 gallons per day. The plan for disposing of this waste is to use it during the summer season for the sprinkling of the mill yard and adjacent streets,

and to treat it in winter by evaporation, so that under this plan none of this waste will hereafter be discharged into the river.

The remaining wastes mentioned in the report of your engineer are the general wastes of the mill, no estimate of the amount of which is presented. It is proposed to collect these wastes in a basin having apparently a capacity of about 15,000 gallons, to be formed in the bottom of the old raceway in the mill yard, from which, after sedimentation and without further treatment, they are to be allowed to overflow into the river. It is proposed to pump the sludge from this basin up to the sludge press over the machine waste tank, and dispose of it in connection with the sludge from the machine waste tank. The character of these general wastes is not known, but will consist of the leakage from the machines, washers and other appliances, from the cleaning of machines and floors, and, presumably, the effluent from the stock draining chambers. It is not practicable to make an accurate estimate of the quantity of these wastes. It is likely that they will amount to at least 100,000 gallons per day, and may, apparently, amount to much more than that quantity. While the character of the liquid that will be collected in this way cannot be determined definitely, it is probable that these wastes will resemble a mixture of all of the wastes from the mill.

The Board has carefully considered the plans and information relative thereto presented by your engineer and the report and advice of your consulting engineer. The Board has also examined the results of analyses of the various wastes discharged from this mill and of experiments upon the disposal of this waste and of similar wastes from other mills.

If the quantity of organic matter in the machine wastes continues to be as low as is indicated by some of the recent analyses, copies of which are appended hereto, these wastes could probably be allowed to flow directly into the river, after thorough sedimentation, without creating objectionable conditions therein. Whether they can safely continue to be disposed of in that way will, however, depend very largely upon the care with which the settling tank is maintained and operated, and the frequency and care with which sludge is removed therefrom. If the organic matter in the waste coming from the paper machines should be as high as has been found in other recent samples coming from these machines, a further treatment of these wastes after sedimentation would be necessary, and the best method of treating them, in that case, would probably be by mechanical filtration.

The area of filters designed to receive the sludge from the machine waste tank is, in the opinion of the Board, likely to be insufficient for the purpose, especially in the winter, and at times of wet weather in other seasons of the year, when the sludge is likely to dry slowly, so that its

removal from the beds at sufficiently frequent intervals will be impracticable.

The settling tank designed to receive the wastes from the washing of stock is of ample size for the purpose, but the sludge beds connected with this tank are too limited to provide adequately for the proper disposal of this sludge during the winter season and at times of prolonged wet weather.

The proposed method of disposing of the boiler wastes is to evaporate them during the winter season and use them for the sprinkling of streets in summer. The plans of the evaporators are not shown, but there is no doubt, in the opinion of the Board, that these wastes can be disposed of satisfactorily by evaporation, and there appears to be no objection to using them for the sprinkling of streets in summer.

The character of the general wastes, so called, as already indicated, is likely to be similar to a mixture of all of the wastes from the mill, and, under the circumstances, it is likely, in the opinion of the Board, that these wastes will require further purification before being discharged into the stream. They can probably best be treated in connection with the wastes from the washing of stock, but if they are mixed with those wastes a larger area of filters than proposed will be required.

It is evident that other means for disposing of sludge than those proposed in the plans presented to the Board will have to be provided, and in the treatment of this material the plan suggested by your consulting engineer in a communication to this Board dated March 30, 1908, in response to a request for further information, appears to be a practicable one and the best one to adopt under the existing circumstances. His suggestions are as follows: —

It is perfectly feasible to so arrange the works that all of the sludge from the different tanks can be collected at one point and pumped to some suitable place of disposal. I have not considered myself authorized to find such an area, but there are numerous areas suitable for the purpose within a reasonable distance of the factory, and as the sludge would not be offensive, the selection of the area is a simple matter. It would not be necessary to find an area of sandy soil, the only requisite being that the land is well drained.

The cost of preparing a suitable area for this purpose would not be more than from $500 to $1,000, depending upon the character of the area. The cost of constructing the force main to the area would not be greater than $3,000 if the area should be half a mile distant, since a 6-inch or 8-inch pipe would be ample for the purpose.

If this scheme should be adopted it would be possible, first, to utilize a much larger area for the disposal of the effluent from the washer waste

tank, which it seems to me is quite desirable; second, to construct these beds at a much less expense, since in order to get the area which it is now proposed to use it is necessary to construct concrete side walls for the filters; third, it would make it feasible to clean the tanks at proper intervals, without regard to the atmospheric or other conditions; and fourth, it would be feasible to treat the entire contents of the tanks upon sludge beds rather than to attempt to draw off as much as possible of the less objectionable matter before beginning to discharge upon the sludge beds, as is proposed under the present plans, thus securing more complete purification of the wastes.

I have not the necessary data to make a close estimate of the cost of such a plant, but I think the expense of construction would be but little greater than the expense of constructing the works proposed, and the expense of maintenance would be smaller.

The Board would recommend that the suggestions of your consulting engineer regarding sludge disposal be followed, and that an area suitable for the purpose be selected from among those which can be made available within a reasonable distance of the factory.

A plan for the disposal of the wastes from your mill which would be satisfactory, after the changes now proposed have been made, would, then, be: —

1. To discharge the machine wastes, after thorough sedimentation, directly into the river, provided the organic matter is as low as indicated by some of the recent analyses; or, in case the organic matter in these wastes, after sedimentation, should still be so high as to have an objectionable effect upon the river, to filter them through mechanical filters.

2. To purify washer and general wastes by filtration through the sand or cinder filters proposed for filter and sludge beds on the plans submitted. These filters have an aggregate area of a little less than 2 acres, and this area would be sufficient to treat about 600,000 gallons of such wastes per day, provided that the filters are properly constructed and not less than 3 feet in depth. If the quantity should be greater, additional means of purification will have to be provided.

3. To dispose of the boiler wastes by evaporation or by using them for sprinkling streets, as suggested by your engineer. The residue from evaporation can be disposed of as sludge.

4. To dispose of all of the sludge from the various processes by pumping it to suitable areas, as indicated in the report of your consulting engineer, quoted above.

WELLESLEY (WELLESLEY COLLEGE).

JUNE 4, 1908.

To the Board of Trustees of Wellesley College, Wellesley, Mass.

GENTLEMEN: — The State Board of Health received on May 22, 1908, from the superintendent of grounds of Wellesley College, the following application for advice with reference to enlarging the filter beds for the disposal of the sewage of the college: —

We are sending you herewith plan of filter beds, showing location of proposed connection and open flushing beds. We desire to connect with the filter beds formerly used for Stone Hall, by laying about 190 feet of 8-inch pipe. We also desire to build 2 open flushing tanks of such size as you may recommend, the beds to have three lines of 5-inch underdrains and be covered with 3 feet of suitable sand or gravel. These beds to be used at such times as our large filter beds demand.

The application was accompanied by a plan showing the present and proposed additional filter beds.

The sewage of Wellesley College is collected in a 12-inch pipe about a mile in length, terminating at a settling basin situated a little north of Waban Brook, about .9 of a mile southeast of College Hall and not far from the Charles River. From the settling tank the sewage is applied to 2 filter beds, having a total area of about 4 acres, through drains laid at intervals of 8 feet and at a depth of from 1½ to about 5 feet beneath the surface of the beds, each drain having branches 7 feet apart, extending downward. The filter beds are not underdrained, the effluent finding its way through the ground to the adjacent streams. This area has now been in use for about five years, and it appears that the distributing pipes in the filters are becoming clogged. In order to relieve this clogging it is proposed to build 2 open filter beds, having a total area of about 5,000 square feet, in low land not far from the present filters, and to flush the sewage through the distributing pipes and discharge it upon these filters. It is also proposed to use another small subsurface filtering area, of about .35 of an acre, constructed several years ago to dispose of the sewage of Stone Hall but which has not been in use for about five years.

The Board has caused the locality to be examined by one of its engineers and has carefully considered the plan and information presented therewith.

It would be impracticable, in the opinion of the Board, to flush the distributing pipes to the proposed filters in the manner proposed, and in that way increase materially the capacity of those filters. Experi-

ments upon the filtration of sewage by applying it intermittently to sand or gravel filters, through pipes laid beneath the surface, and the experience of many years in the operation of such areas, have shown that the distributing pipes through which the sewage is applied become clogged after a few years' use, and satisfactory results can be obtained in the operation of such filters only by relaying the distributing pipes from time to time as clogging makes it necessary. The filters now in use for the disposal of the sewage at Wellesley College have operated as long as such filters can reasonably be expected to operate without relaying the distributing pipes, and if the pipes should be taken up and relaid between the lines as they now exist these filters would, in the opinion of the Board, continue to dispose of the sewage satisfactorily for several years longer.

The Board would recommend the relaying of the pipes in the present filters half way between the present distributing pipes and at a depth of about 1½ feet beneath the surface of the filters. It is not desirable to lay branches extending down to a greater depth. Care should be taken in covering the joints of the pipes so as not to clog them with sand and to allow as free an outlet for the sewage as practicable.

There is no objection to the use of the area formerly used for disposing of the sewage of Stone Hall, and it would probably be advisable to complete the filter beds now under construction, but it would be best to provide subsurface pipes through which to apply the sewage to these filters also. It is furthermore desirable, in relaying the pipes, to divide the whole area into as many as three nearly equal portions, and provision should be made for using at least two of the areas alternately, allowing the third one to rest for a few weeks at a time. If the quantity of sewage has increased materially recently, or is likely to increase materially in the near future, it will probably be best to enlarge the filtration area, which can apparently be done without difficulty. It would be best to continue in the future the method of subsurface application of sewage to all of the filters.

Miscellaneous.

The following is the substance of the action of the Board during the year in reply to applications for advice relative to miscellaneous matters: —

Lynn.

Nov. 5, 1908.

To the Board of Health of the City of Lynn.

Gentlemen: — The State Board of Health received from you on May 15, 1908, an application requesting the examination of the flats in Lynn harbor for the purpose of ascertaining whether the said flats

are contaminated by sewage to such an extent as to injure the clams therein, and in response the Board has caused the sewer outlets and flats in the harbor to be examined, and samples of clams collected in various parts of the harbor, both along the Lynn and Nahant shores and in the adjacent estuaries of the Saugus and Pines rivers, to be analyzed.

The results of the analyses show the presence of bacteria characteristic of sewage in shellfish collected in all parts of the harbor and in the rivers, and, in the opinion of the Board, clams taken in the harbor or the adjacent estuaries are likely to be injurious to health if used for food.

Under the provisions of section 113 of chapter 91 of the Revised Laws, the State Board of Health is authorized to examine all complaints which may be brought to its notice relative to the contamination of tidal waters and flats in this Commonwealth by sewage or other causes, to determine as nearly as may be the bounds of such contamination, and, if necessary, mark such bounds, and it may also, in writing, request the Commissioners on Inland Fisheries and Game to prohibit the taking of certain shellfish, including clams, from such contaminated waters and flats. Penalties are also provided for infractions of this law.

Acting under that law the State Board of Health has requested the Commissioners on Inland Fisheries and Game to prohibit the taking of clams from the waters or flats of Lynn harbor or its tributaries, including the Saugus and Pines rivers, north of a line drawn from the Pines Hotel at the Point of Pines to Bass Point, the southernmost point of the peninsula of Nahant, until they receive further notice from this Board.

MALDEN.

SEPT. 3, 1908.

To the Board of Health of the City of Malden.

GENTLEMEN: — Complaint has been made to this Board of the objectionable condition of the Malden River and a bad odor arising therefrom, and the Board has recently caused an examination of the river and the sources of pollution thereof to be made by its engineer, and has examined the results of the analyses of samples of water collected from the stream at various points and at different times, and the analyses of effluents discharged into it from various manufacturing establishments along its course.

The results of the examination show that the river is very badly polluted at the present time, principally by manufacturing wastes from a number of factories and works, practically all of which are situated within the limits of the city of Malden. There is no doubt that, if the objectionable wastes now discharged into the stream from these

factories and works should be purified or disposed of by discharging them into the sewers, the condition of the river would quickly improve and again become satisfactory.

The sewers of the city of Malden and the metropolitan sewerage system are available and can be used for the disposal of these wastes, though in some cases it will be necessary to pass them first through settling tanks, and perhaps to apply some further form of treatment to prevent them from causing objectionable conditions in the sewers. A few of the establishments are so situated that it may be possible for them to purify their wastes to such an extent that their discharge into the river may be continued without objection.

Your board has the power to prevent further pollution of the Malden River and its tributaries by wastes from these establishments, and prevent the nuisance which now results therefrom, and the Board calls your attention to these objectionable conditions in order that you may take such action as may be necessary to prevent further nuisance from this cause.

A list of the establishments from which polluting wastes are now discharged into the stream in considerable quantity, together with a statement of the general character of the wastes therefrom now requiring purification, is appended hereto.

The Board will upon request furnish your board or the owners of the works herein mentioned with such information as its engineer has collected relative to the amount and character of the wastes which were being discharged from each of the establishments at the time the recent investigations of the Board were made, and the Board will give such further assistance as it can by advising you or the owners of the mills as to any plans that you or they may wish to present for the treatment of the wastes from these establishments before discharging them into the sewers, or as to plans for purifying such of these wastes as it is practicable to treat in that way, so that they may continue to be discharged into the river or its tributaries.

The works from which polluting wastes are being discharged into the Malden River or its tributaries within the limits of the city of Malden are as follows: —

1. The works of the Cochrane Manufacturing Company, located on Barrett's Lane, west of Main Street and north of Pleasant Street. The wastes which are the principal cause of the pollution of the stream from these works are: (1) a solution in which cloth is boiled; (2) spent dye liquors and miscellaneous wastes from the color house where the dyes are mixed; (3) mordants used in connection with the printing; (4) the water used in washing the goods. Only a part of the water used

in washing contains such an amount of organic matter as to cause serious pollution of the stream, and provision should be made for keeping these objectionable portions, consisting for the most part of the water from the first washing of the goods, out of the stream.

2. The New England Dyeing and Cleansing Works, situated on Charles Street, east of the Malden River. The polluting wastes discharged from this mill consist of wash waters, aniline dyes and water used in washing. It is also desirable that a water-closet connected with the sewer be provided in this mill and the present method of disposing of the sewage therefrom discontinued.

3. Robinson Brothers & Company Soap Works, located on the easterly side of the river. The polluting wastes consist of spent lye and wastes in rinsing from kettles.

4. Malden and Melrose Gas Light Company, situated on the westerly side of the river on Commercial Street. The wastes from these works are in part reclaimed and in part are discharged into the river. The wastes discharged into the river are first passed through a settling tank, but this is of inadequate capacity for removing all of the solid and polluting matters that may be removed in this way, and the effluent from the tank will in any case be a serious pollution of the stream. It would be practicable to take these wastes into the sewer without objection if they were first treated with precipitants in a properly designed settling tank and then filtered, so as to remove from them matters which might cause objectionable conditions in the sewers. Wastes from such works are discharged into sewers in other places at the present time, after treatment, without objection.

5. Boston Rubber Shoe Company, factory No. 1, situated a short distance above Medford Street. The wastes from this mill are largely those resulting from the boiling and washing of rubber and the washing of cloth, and practically all of them contain a large quantity of organic matter. They can, after being passed through properly designed settling tanks, be admitted to the sewers without objection.

6. The Webster & Company Tannery, situated a short distance below Medford Street. Practically all of the water discharged from this factory contains an excessive amount of organic matter of a putrescible character, which has a very serious effect on the stream. These wastes can be discharged into the sewers without objection if they are first passed through a properly designed settling tank. It is also important that the sewage from the operatives in the mill be diverted from the river and discharged into the sewers.

SHERBORN (JACOB LANDER).

SEPT. 3, 1908.

TO MR. JACOB LANDER, *Sherborn, Mass.*

DEAR SIR: — The State Board of Health has considered your request for the approval of the location and construction of a slaughterhouse to be situated between Beaver Street and the tracks of the New York, New Haven & Hartford Railroad, east of First Street, in Sherborn, but finds upon inquiry from the board of selectmen of the town of Sherborn that no application for a license to slaughter at the location in question has been made to that board, as required by chapter 75 of the Revised Laws.

Under the circumstances the State Board of Health declines to approve the location and construction of a slaughterhouse as proposed in your petition.

EXAMINATION OF PUBLIC WATER SUPPLIES.

EXAMINATION OF PUBLIC WATER SUPPLIES.

The usual chemical analyses of the principal sources of public supply in the State have been made during the year and are presented in the two following tables, the first of which contains averages of analyses of the surface-water supplies and the second the averages of analyses of samples from the ground-water supplies.

Averages of Chemical Analyses of Surface-water Sources for the Year 1908.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia.			Chlorine.	Nitrogen as		Oxygen Consumed.	Hardness.
				Free.	Albuminoid. Total.	Albuminoid. Suspended.		Nitrates.	Nitrites.		
Metropolitan Water District.	Wachusett Reservoir, upper end.	.26	3.45	.0018	.0133	.0024	0.23	.0025	.0000	.35	0.6
	Wachusett Reservoir, surface, near dam.	.18	2.96	.0019	.0123	.0020	0.25	.0019	.0001	.26	0.6
	Wachusett Reservoir, bottom, near dam.	.19	2.87	.0018	.0101	.0017	0.25	.0039	.0001	.30	0.6
	Wachusett Aqueduct, .	.26	3.39	.0020	.0112	.0013	0.26	.0050	.0001	.36	0.9
	Sudbury Reservoir, .	.19	3.16	.0026	.0124	.0021	0.31	.0053	.0001	.30	0.9
	Framingham Reservoir No. 3.	.19	3.30	.0018	.0133	.0028	0.30	.0056	.0001	.31	1.1
	Hopkinton Reservoir, .	.57	4.08	.0022	.0166	.0023	0.37	.0023	.0001	.66	0.8
	Ashland Reservoir, .	.55	4.12	.0024	.0186	.0025	0.32	.0022	.0001	.62	0.8
	Framingham Reservoir No. 2.	.66	4.17	.0027	.0197	.0027	0.35	.0026	.0000	.68	1.0
	Lake Cochituate, .	.26	5.40	.0023	.0218	.0058	0.59	.0027	.0001	.43	2.1
	Chestnut Hill Reservoir,	.20	3.65	.0019	.0119	.0020	0.31	.0064	.0001	.29	1.0
	Weston Reservoir, .	.18	3.42	.0015	.0118	.0018	0.31	.0072	.0001	.29	1.0
	Dug Pond, .	.12	5.11	.0028	.0189	.0031	0.66	.0059	.0001	.26	1.8
	Spot Pond, .	.12	3.55	.0021	.0135	.0023	0.35	.0020	.0000	.25	1.1
	Tap in State House, .	.19	3.60	.0010	.0118	.0024	0.34	.0095	.0001	.27	1.2
	Tap in Revere, .	.13	3.90	.0010	.0119	.0016	0.35	.0024	.0000	.24	1.2
	Tap in Quincy, .	.17	3.59	.0009	.0096	.0009	0.35	.0081	.0001	.25	1.2
Abington, . .	Big Sandy Pond, .	.11	3.05	.0029	.0147	.0018	0.70	.0005	.0000	.19	0.5
	Little Sandy Pond, .	.06	4.28	.0021	.0208	.0067	1.21	.0005	.0000	.29	0.2
Adams, . . .	Dry Brook, .	.23	9.27	.0016	.0091	.0016	0.13	.0040	.0000	.32	7.1
	Bassett Brook, .	.02	5.53	.0025	.0041	.0004	0.12	.0117	.0000	.08	4.1

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Suspended.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
Amherst,	Amethyst Brook Reservoir.	.19	3.12	.0010	.0097	.0027	0.16	.0017	.0000	.24	0.6
	Lower Reservoir,	.31	3.55	.0029	.0094	.0018	0.17	.0030	.0000	.38	0.5
Andover,	Haggett's Pond,	.17	3.02	.0012	.0138	.0015	0.35	.0012	.0000	.31	1.0
Ashfield,	Bear Swamp Brook,	.27	5.22	.0009	.0087	.0005	0.12	.0020	.0000	.42	2.7
Athol,	Phillipston Reservoir,	.43	3.05	.0025	.0342	.0160	0.21	.0015	.0001	.49	0.4
	Buckman Brook Reservoir.	.26	3.34	.0028	.0295	.0138	0.18	.0020	.0000	.40	0.6
Barre,	Reservoir,	.19	2.84	.0023	.0179	.0044	0.18	.0013	.0001	.27	0.7
Braintree,	Little Pond,	.35	5.40	.0034	.0204	.0008	1.07	.0260	.0002	.57	1.3
Brockton,	Salisbury Brook Reservoir.[1]	.46	4.11	.0013	.0237	.0064	0.44	.0009	.0001	.62	0.7
	Silver Lake,	.13	3.23	.0016	.0134	.0026	0.66	.0002	.0000	.26	0.4
Cambridge,	Upper Hobbs Brook Reservoir.	.52	5.71	.0028	.0288	.0057	0.46	.0062	.0001	.67	2.0
	Lower Hobbs Brook Reservoir.	.20	5.78	.0028	.0250	.0038	0.46	.0044	.0001	.40	2.1
	Stony Brook Reservoir,	.38	5.82	.0021	.0197	.0028	0.54	.0135	.0001	.50	2.3
	Fresh Pond,	.26	6.48	.0061	.0288	.0121	0.61	.0174	.0004	.40	2.9
Cheshire,	Thunder Brook,	.14	5.75	.0006	.0038	.0006	0.11	.0040	.0000	.15	4.2
	Kitchen Brook,	.06	6.20	.0006	.0024	.0006	0.09	.0040	.0000	.08	4.3
Chester,	Austin Brook Reservoir.	.11	4.35	.0002	.0044	.0006	0.15	.0050	.0000	.14	1.6
Chicopee,	Morton Brook,	.06	4.75	.0004	.0024	.0002	0.13	.0030	.0000	.09	0.5
	Cooley Brook,	.21	4.35	.0002	.0064	.0012	0.14	.0030	.0000	.18	0.8
	Abbe Reservoir,	.23	4.85	.0030	.0238	.0046	0.28	.0060	.0006	.23	1.3
Concord,	Sandy Pond,	.04	2.83	.0007	.0120	.0036	0.31	.0011	.0000	.13	1.0
Dalton,	Egypt Brook Reservoir.	.30	3.62	.0034	.0102	.0020	0.09	.0132	.0000	.37	1.0
Danvers,	Middleton Pond,	.54	4.47	.0016	.0180	.0018	0.42	.0008	.0000	.67	1.1
Deerfield,	Roaring Brook,	.05	2.95	.0002	.0030	.0000	0.13	.0040	.0000	.10	3.6
Easthampton,	Bassett Brook,	.28	4.10	.0006	.0088	.0004	0.17	.0050	.0001	.30	1.1
Fall River,	North Watuppa Lake,	.20	4.12	.0019	.0182	.0032	0.65	.0017	.0001	.36	0.7
Falmouth,	Long Pond,	.03	3.02	.0006	.0093	.0011	0.97	.0007	.0000	.08	0.3
Fitchburg,	Meetinghouse Pond,	.11	2.69	.0031	.0128	.0027	0.17	.0008	.0001	.26	0.5
	Scott Reservoir,	.19	2.99	.0063	.0197	.0080	0.19	.0018	.0000	.30	0.3
	Wachusett Lake,	.13	2.29	.0039	.0140	.0040	0.15	.0007	.0001	.26	0.2
Gardner,	Crystal Lake,	.11	5.11	.0025	.0148	.0016	0.33	.0071	.0001	.21	1.8
Gloucester,	Dike's Brook Reservoir.	.28	3.78	.0016	.0155	.0033	0.97	.0005	.0000	.33	0.2
	Wallace Reservoir,	.31	4.28	.0019	.0164	.0038	1.26	.0010	.0001	.37	0.3

[1] Not used in 1908.

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia.			Chlorine.	Nitrogen as		Oxygen Consumed.	Hardness.
				Free.	Albuminoid.			Nitrates.	Nitrites.		
					Total.	Sus-pended.					
Gloucester, . .	Haskell Brook Reservoir.	.44	3.91	.0052	.0137	.0023	.94	.0022	.0001	.31	0.4
Great Barrington, .	East Mountain Reservoir.	.14	4.88	.0011	.0073	.0011	.11	.0006	.0001	.20	3.3
	Green River, . .	.02	9.24	.0005	.0031	.0003	.12	.0136	.0001	.08	7.9
Greenfield, . .	Upper reservoir on Glen Brook.	.04	4.87	.0029	.0067	.0016	.15	.0069	.0001	.13	3.1
	Lower reservoir on Glen Brook.	.05	5.31	.0037	.0056	.0009	.15	.0061	.0001	.10	3.1
Hadley, . . .	Hart's Brook Reservoir.	.07	4.71	.0033	.0074	.0021	.19	.0004	.0000	.10	2.4
Hatfield, . . .	Reservoir, . . .	.12	4.34	.0011	.0069	.0012	.17	.0215	.0000	.18	1.8
Haverhill, . .	Johnson's Pond, . .	.17	4.40	.0015	.0163	.0026	.44	.0017	.0001	.32	2.0
	Crystal Lake, . .	.22	3.89	.0014	.0154	.0020	.33	.0008	.0001	.36	1.0
	Kenoza Lake, . .	.15	3.96	.0018	.0152	.0018	.41	.0013	.0001	.31	1.7
	Lake Saltonstall, . .	.06	5.71	.0012	.0145	.0018	.55	.0012	.0000	.19	2.5
	Lake Pentucket, . .	.12	4.66	.0013	.0152	.0024	.45	.0008	.0001	.28	1.8
	Millvale Reservoir, .	.47	4.14	.0029	.0198	.0043	.37	.0017	.0001	.59	1.5
Hingham, . .	Accord Pond, . .	.24	3.28	.0007	.0112	.0014	.68	.0015	.0001	.33	0.4
Holden, . . .	Muschopauge Lake, .	.08	3.40	.0019	.0098	.0008	.28	.0013	.0000	.17	1.2
Holyoke, . . .	Whiting Street Reservoir.	.10	4.31	.0030	.0164	.0029	.19	.0004	.0000	.20	2.3
	Fomer Reservoir, .	.21	4.45	.0021	.0081	.0012	.15	.0040	.0001	.28	1.8
	Wright and Ashley Pond.	.07	5.73	.0031	.0175	.0041	.18	.0007	.0000	.18	3.1
	High-service Reservoir,	.18	5.20	.0032	.0222	.0041	.18	.0008	.0001	.34	2.2
Hudson, . . .	Gates Pond, . . .	.12	3.04	.0019	.0151	.0034	.25	.0030	.0001	.21	0.9
	Fosgate Brook, . .	.36	4.88	.0035	.0113	.0015	.20	.0048	.0001	.39	1.5
Huntington, . .	Cold Brook Reservoir,	.12	3.03	.0005	.0041	.0004	.13	.0020	.0000	.19	0.9
Ipswich, . . .	Dow's Brook Reservoir,	.22	4.97	.0023	.0160	.0023	.67	.0039	.0001	.34	1.6
Lawrence, . .	Merrimack River, filtered.	.34	5.10	.0088	.0093	.0012	.40	.0177	.0003	.47	1.6
	Distributing Reservoir,	.30	4.64	.0051	.0087	.0012	.39	.0192	.0003	.41	1.7
Lee, ...	Upper reservoir on Codding Brook.	.27	2.47	.0051	.0207	.0039	.10	.0007	.0000	.44	0.6
	Lower reservoir on Codding Brook.	.20	3.39	.0039	.0094	.0011	.09	.0035	.0000	.28	1.8
	Basin Pond Brook, .	.38	4.42	.0055	.0115	.0015	.14	.0050	.0000	.49	1.9
Lenox, . . .	Reservoir, . . .	.07	7.17	.0019	.0124	.0025	.11	.0056	.0001	.13	5.0
Leominster, . .	Morse Reservoir, . .	.23	2.62	.0034	.0198	.0053	.17	.0012	.0001	.31	0.1
	Haynes Reservoir, .	.25	2.48	.0046	.0279	.0089	.17	.0007	.0000	.37	0.1
	Fall Brook Reservoir, .	.12	2.70	.0016	.0133	.0034	.17	.0007	.0000	.28	0.2
Longmeadow, .	Cooley Brook, . .	.08	4.05	.0007	.0062	.0013	.20	.0185	.0000	.11	2.6

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Suspended.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
Lynn,	Birch Reservoir,	0.31	4.10	.0054	.0208	.0046	0.63	.0012	.0001	0.42	1.4
	Breed's Reservoir,	0.37	4.40	.0041	.0185	.0029	0.63	.0017	.0001	0.48	1.3
	Walden Reservoir,	0.40	4.55	.0047	.0199	.0034	0.67	.0018	.0001	0.51	1.7
	Hawkes Reservoir,	0.37	4.76	.0053	.0193	.0029	0.57	.0037	.0001	0.49	1.6
	Saugus River,	0.77	7.21	.0051	.0281	.0028	0.76	.0019	.0001	0.83	3.7
Manchester,	Round Pond,	0.58	4.39	.0030	.0194	.0032	0.86	.0010	.0000	0.59	0.8
	Gravel Pond,	0.10	4.54	.0017	.0153	.0020	0.83	.0005	.0000	0.23	0.7
Marlborough,	Lake Williams,	0.11	4.73	.0023	.0173	.0024	0.53	.0027	.0001	0.23	1.5
	Millham Brook Reservoir.	0.38	4.42	.0048	.0190	.0036	0.39	.0060	.0001	0.43	1.2
Maynard,	White Pond,	0.06	2.89	.0009	.0106	.0015	0.32	.0037	.0000	0.15	0.7
Milford,	Charles River, filtered,	0.19	3.54	.0011	.0061	–	0.31	.0102	.0000	–	0.9
Montague,	Lake Pleasant,	0.05	2.41	.0017	.0074	.0015	0.15	.0025	.0000	0.13	0.4
Nantucket,	Wannacomet Pond,	0.07	6.83	.0033	.0123	.0021	2.23	.0005	.0000	0.15	1.2
New Bedford,	Old Storage Reservoir,[1]	1.23	5.22	.0031	.0259	.0035	0.58	.0012	.0000	1.14	0.9
	Little Quittacas Pond,	0.26	4.01	.0033	.0190	.0027	0.58	.0002	.0000	0.39	0.7
	Great Quittacas Pond,	0.39	3.53	.0032	.0205	.0026	0.59	.0003	.0000	0.54	0.5
North Adams,	Notch Brook Reservoir,	0.04	7.46	.0025	.0071	.0019	0.08	.0012	.0001	0.10	6.1
	Broad Brook,	0.12	4.95	.0007	.0056	.0005	0.08	.0065	.0001	0.22	3.4
Northampton,	Middle Reservoir,	0.25	4.78	.0019	.0103	.0015	0.14	.0025	.0000	0.31	1.4
	Mountain Street Reservoir.	0.09	3.61	.0012	.0081	.0015	0.11	.0008	.0001	0.17	1.6
	West Brook,	0.11	4.24	.0009	.0053	.0006	0.14	.0040	.0001	0.16	1.7
North Andover,	Great Pond,	0.19	3.70	.0026	.0163	.0016	0.40	.0008	.0000	0.33	1.3
Northborough,	Lower Reservoir,	0.55	4.08	.0040	.0230	.0025	0.31	.0030	.0001	0.56	1.0
Northbridge,	Cook Allen Reservoir,	0.24	3.05	.0029	.0185	.0039	0.20	.0003	.0000	0.34	0.4
North Brookfield,	Doane Pond,	0.35	2.87	.0023	.0179	.0041	0.14	.0007	.0000	0.31	0.3
	North Pond,	0.42	2.08	.0039	.0335	.0130	0.17	.0007	.0001	0.53	0.3
Norwood,	Buckmaster Pond,	0.15	3.87	.0031	.0156	.0036	0.53	.0027	.0001	0.22	0.8
Orange,	Distributing Reservoir,	0.01	2.57	.0008	.0035	.0009	0.12	.0015	.0000	0.08	0.4
Palmer,	Lower Reservoir,	0.25	3.31	.0029	.0152	.0029	0.17	.0015	.0000	0.29	0.7
Peabody,	Brown's Pond,	0.16	3.32	.0016	.0138	.0027	0.75	.0097	.0001	0.26	1.0
	Spring Pond,	0.10	5.46	.0019	.0140	.0032	0.73	.0062	.0001	0.18	1.9
	Suntaug Lake,	0.06	4.00	.0014	.0160	.0031	0.74	.0012	.0001	0.16	2.0
Pittsfield,	Ashley Lake,	0.15	5.40	.0119	.0138	.0035	0.16	.0075	.0000	0.26	4.1

[1] Not used in 1908.

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Sus-pended.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
Pittsfield,	Ashley Brook,	.15	4.65	.0029	.0103	.0017	0.13	.0065	.0000	.22	4.3
	Hathaway Brook,	.06	9.70	.0009	.0062	.0005	0.14	.0080	.0000	.13	8.2
	Mill Brook,	.11	4.47	.0010	.0072	.0003	0.10	.0045	.0000	.18	3.7
	Sacket Brook,	.11	6.25	.0017	.0075	.0020	0.12	.0150	.0000	.17	5.6
Plymouth,	Little South Pond,	.02	2.41	.0022	.0150	.0039	0.66	.0005	.0000	.12	0.1
	Great South Pond,	.01	3.06	.0015	.0137	.0027	0.66	.0003	.0000	.07	0.1
	Boot Pond,[1]	.02	2.59	.0016	.0163	.0054	0.63	.0005	.0000	.11	0.1
Randolph,	Great Pond,	.39	4.14	.0014	.0156	.0022	0.62	.0040	.0001	.46	0.8
Rockport,	Cape Pond,	.19	9.94	.0057	.0275	.0106	3.38	.0016	.0002	.35	1.6
Salem,	Wenham Lake,	.25	5.50	.0050	.0201	.0046	0.91	.0045	.0002	.40	2.0
	Longham Reservoir,	.76	7.08	.0098	.0327	.0115	1.05	.0082	.0004	.72	2.0
Southbridge,	Hatchet Brook Reservoir No. 3.	.28	2.86	.0027	.0237	.0073	0.18	.0009	.0000	.39	0.5
	Hatchet Brook Reservoir No. 4.	.53	3.43	.0116	.0292	.0095	0.19	.0007	.0001	.50	0.6
South Hadley,	Leaping Well Reservoir,	.12	3.02	.0038	.0303	.0129	0.19	.0032	.0002	.16	0.5
	Buttery Brook Reservoir.	.17	4.28	.0058	.0157	.0040	0.35	.0332	.0003	.16	0.8
Spencer,	Shaw Pond,	.10	2.65	.0009	.0124	.0012	0.18	.0027	.0000	.19	0.8
Springfield,	Ludlow Basin,	.22	2.59	.0016	.0139	.0035	0.16	.0011	.0000	.28	0.7
	Ludlow Canal,	.41	3.71	.0013	.0135	.0018	0.18	.0024	.0001	.46	1.0
	Ludlow Reservoir,	.28	2.84	.0011	.0185	.0056	0.16	.0004	.0000	.32	0.7
	Chapin Pond,[1]	.06	2.45	.0023	.0180	.0038	0.13	.0002	.0000	.20	0.3
	Five Mile Pond,[1]	.10	2.45	.0027	.0188	.0039	0.17	.0007	.0000	.22	0.3
	Loon Pond,[1]	.05	2.97	.0024	.0167	.0028	0.26	.0007	.0001	.15	0.7
	Borden Brook,[1]	.74	4.11	.0018	.0169	.0024	0.21	.0020	.0001	.80	1.0
	Pebble Brook,[1]	.48	3.47	.0015	.0183	.0044	0.15	.0010	.0001	.60	0.9
	Westfield Little River,[1]	.61	4.12	.0014	.0179	.0035	0.22	.0020	.0001	.71	1.1
Stockbridge,	Lake Averic,	.13	5.79	.0032	.0172	.0039	0.10	.0017	.0001	.26	4.3
Stoughton,	Muddy Brook,	.19	2.95	.0007	.0074	–	0.38	.0047	.0000	.20	0.6
Taunton,	Assawompsett Pond,	.31	3.32	.0017	.0164	.0029	0.55	.0008	.0000	.47	0.5
	Elder's Pond,	.12	3.03	.0010	.0148	.0025	0.52	.0008	.0000	.28	0.5
	Long Pond,	.58	3.41	.0012	.0152	.0014	0.54	.0005	.0000	.65	0.4
Wakefield,	Crystal Lake,	.22	5.15	.0025	.0211	.0048	0.69	.0053	.0001	.32	1.9
Wareham,	Jonathan's Pond,	.01	2.41	.0010	.0081	.0014	0.70	.0003	.0000	.08	0.0
Wayland,	Snake Brook Reservoir,	.52	4.85	.0039	.0167	.0019	0.36	.0085	.0001	.46	1.4

[1] Not used in 1908.

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Suspended.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
Lynn, . . .	Birch Reservoir, . .	0.31	4.10	.0054	.0208	.0046	0.63	.0012	.0001	0.42	1.4
	Breed's Reservoir, .	0.37	4.40	.0041	.0185	.0029	0.63	.0017	.0001	0.48	1.3
	Walden Reservoir, .	0.40	4.55	.0047	.0199	.0034	0.67	.0018	.0001	0.51	1.7
	Hawkes Reservoir, .	0.37	4.76	.0053	.0193	.0029	0.57	.0037	.0001	0.49	1.6
	Saugus River, . .	0.77	7.21	.0051	.0281	.0028	0.76	.0019	.0001	0.83	3.7
Manchester, . .	Round Pond, . .	0.58	4.39	.0030	.0194	.0032	0.86	.0010	.0000	0.59	0.8
	Gravel Pond, . .	0.10	4.54	.0017	.0153	.0020	0.83	.0005	.0000	0.23	0.7
Marlborough, . .	Lake Williams, . .	0.11	4.73	.0023	.0173	.0024	0.53	.0027	.0001	0.23	1.5
	Millham Brook Reservoir.	0.38	4.42	.0048	.0190	.0036	0.39	.0060	.0001	0.43	1.2
Maynard, . .	White Pond, . . .	0.06	2.89	.0009	.0106	.0015	0.32	.0037	.0000	0.15	0.7
Milford, . . .	Charles River, filtered,	0.19	3.54	.0011	.0061	–	0.31	.0102	.0000	–	0.9
Montague, . .	Lake Pleasant, . .	0.05	2.41	.0017	.0074	.0015	0.15	.0025	.0000	0.13	0.4
Nantucket, . .	Wannacomet Pond, .	0.07	6.83	.0033	.0123	.0021	2.23	.0005	.0000	0.15	1.2
New Bedford, .	Old Storage Reservoir,[1]	1.23	5.22	.0031	.0259	.0035	0.58	.0012	.0000	1.14	0.9
	Little Quittacas Pond,	0.26	4.01	.0033	.0190	.0027	0.58	.0002	.0000	0.39	0.7
	Great Quittacas Pond,	0.39	3.53	.0032	.0205	.0026	0.59	.0003	.0000	0.54	0.5
North Adams, .	Notch Brook Reservoir,	0.04	7.46	.0025	.0071	.0019	0.08	.0012	.0001	0.10	6.1
	Broad Brook, . .	0.12	4.95	.0007	.0056	.0005	0.08	.0065	.0001	0.22	3.4
Northampton, . .	Middle Reservoir, .	0.25	4.78	.0019	.0103	.0015	0.14	.0025	.0000	0.31	1.4
	Mountain Street Reservoir.	0.09	3.61	.0012	.0081	.0015	0.11	.0008	.0001	0.17	1.6
	West Brook, . . .	0.11	4.24	.0009	.0053	.0008	0.14	.0040	.0001	0.16	1.7
North Andover, .	Great Pond, . . .	0.19	3.70	.0026	.0163	.0016	0.40	.0008	.0000	0.33	1.3
Northborough, .	Lower Reservoir, . .	0.55	4.08	.0040	.0230	.0025	0.31	.0030	.0001	0.56	1.0
Northbridge, . .	Cook Allen Reservoir, .	0.24	3.05	.0029	.0135	.0029	0.20	.0003	.0000	0.34	0.4
North Brookfield, .	Doane Pond, . . .	0.35	2.87	.0023	.0179	.0041	0.14	.0007	.0000	0.31	0.3
	North Pond, . . .	0.42	2.08	.0039	.0335	.0130	0.17	.0007	.0001	0.55	0.3
Norwood, . .	Buckmaster Pond, .	0.15	3.87	.0031	.0156	.0036	0.53	.0027	.0001	0.22	0.8
Orange, . . .	Distributing Reservoir,	0.01	2.57	.0008	.0035	.0009	0.12	.0015	.0000	0.08	0.4
Palmer, . . .	Lower Reservoir, . .	0.25	3.31	.0029	.0152	.0029	0.17	.0015	.0000	0.29	0.7
Peabody, . .	Brown's Pond, . .	0.16	3.32	.0016	.0138	.0027	0.75	.0097	.0001	0.26	1.0
	Spring Pond, . .	0.10	5.46	.0019	.0140	.0032	0.73	.0062	.0001	0.18	1.9
	Suntaug Lake, . .	0.06	4.00	.0014	.0160	.0031	0.74	.0012	.0001	0.16	2.0
Pittsfield, . .	Ashley Lake, . .	0.15	5.40	.0119	.0138	.0035	0.16	.0075	.0000	0.26	4.1

[1] Not used in 1908.

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Suspended.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
Pittsfield,	Ashley Brook,	.15	4.65	.0029	.0103	.0017	0.13	.0065	.0000	.22	4.3
	Hathaway Brook,	.06	9.70	.0009	.0062	.0005	0.14	.0080	.0000	.13	8.2
	Mill Brook,	.11	4.47	.0010	.0072	.0003	0.10	.0045	.0000	.18	3.7
	Sacket Brook,	.11	6.25	.0017	.0075	.0020	0.12	.0150	.0000	.17	5.6
Plymouth,	Little South Pond,	.02	2.41	.0022	.0150	.0039	0.66	.0005	.0000	.12	0.1
	Great South Pond,	.01	3.06	.0015	.0137	.0027	0.66	.0003	.0000	.07	0.1
	Boot Pond,[1]	.02	2.59	.0016	.0163	.0054	0.63	.0005	.0000	.11	0.1
Randolph,	Great Pond,	.39	4.14	.0014	.0156	.0022	0.62	.0040	.0001	.46	0.8
Rockport,	Cape Pond,	.19	9.94	.0057	.0275	.0106	3.38	.0016	.0002	.35	1.6
Salem,	Wenham Lake,	.25	5.50	.0050	.0201	.0046	0.91	.0045	.0002	.40	2.0
	Longham Reservoir,	.76	7.08	.0098	.0327	.0115	1.05	.0082	.0004	.72	2.0
Southbridge,	Hatchet Brook Reservoir No. 3.	.28	2.86	.0027	.0237	.0073	0.18	.0009	.0000	.39	0.5
	Hatchet Brook Reservoir No. 4.	.53	3.43	.0116	.0292	.0095	0.19	.0007	.0001	.50	0.6
South Hadley,	Leaping Well Reservoir,	.12	3.02	.0038	.0303	.0129	0.19	.0032	.0002	.16	0.5
	Buttery Brook Reservoir.	.17	4.28	.0058	.0157	.0040	0.35	.0332	.0003	.16	0.8
Spencer,	Shaw Pond,	.10	2.65	.0009	.0124	.0012	0.18	.0027	.0000	.19	0.8
Springfield,	Ludlow Basin,	.22	2.59	.0016	.0139	.0035	0.16	.0011	.0000	.28	0.7
	Ludlow Canal,	.41	3.71	.0013	.0135	.0018	0.18	.0024	.0001	.46	1.0
	Ludlow Reservoir,	.28	2.84	.0011	.0185	.0056	0.16	.0004	.0000	.32	0.7
	Chapin Pond,[1]	.06	2.45	.0023	.0180	.0038	0.13	.0002	.0000	.20	0.3
	Five Mile Pond,[1]	.10	2.45	.0027	.0188	.0039	0.17	.0007	.0000	.22	0.3
	Loon Pond,[1]	.05	2.97	.0024	.0167	.0028	0.26	.0007	.0001	.15	0.7
	Borden Brook,[1]	.74	4.11	.0018	.0169	.0024	0.21	.0020	.0001	.80	1.0
	Pebble Brook,[1]	.48	3.47	.0015	.0183	.0044	0.15	.0010	.0001	.60	0.9
	Westfield Little River,[1]	.61	4.12	.0014	.0179	.0035	0.22	.0020	.0001	.71	1.1
Stockbridge,	Lake Averic,	.13	5.79	.0032	.0172	.0039	0.10	.0017	.0001	.26	4.3
Stoughton,	Muddy Brook,	.19	2.95	.0007	.0074	–	0.38	.0047	.0000	.20	0.6
Taunton,	Assawompsett Pond,	.31	3.32	.0017	.0164	.0029	0.55	.0008	.0000	.47	0.5
	Elder's Pond,	.12	3.03	.0010	.0148	.0025	0.52	.0008	.0000	.28	0.5
	Long Pond,	.58	3.41	.0012	.0152	.0014	0.54	.0005	.0000	.65	0.4
Wakefield,	Crystal Lake,	.22	5.15	.0025	.0211	.0048	0.69	.0053	.0001	.32	1.9
Wareham,	Jonathan's Pond,	.01	2.41	.0010	.0081	.0014	0.70	.0003	.0000	.08	0.0
Wayland,	Snake Brook Reservoir,	.52	4.85	.0039	.0167	.0019	0.36	.0085	.0001	.46	1.4

[1] Not used in 1908.

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Suspended.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
Lynn,	Birch Reservoir,	0.31	4.10	.0054	.0208	.0046	0.63	.0012	.0001	0.42	1.4
	Breed's Reservoir,	0.37	4.40	.0041	.0185	.0029	0.63	.0017	.0001	0.48	1.3
	Walden Reservoir,	0.40	4.55	.0047	.0199	.0034	0.67	.0018	.0001	0.51	1.7
	Hawkes Reservoir,	0.37	4.76	.0053	.0198	.0029	0.57	.0037	.0001	0.49	1.6
	Saugus River,	0.77	7.21	.0061	.0281	.0028	0.76	.0019	.0001	0.83	3.7
Manchester,	Round Pond,	0.58	4.39	.0030	.0194	.0032	0.86	.0010	.0000	0.59	0.8
	Gravel Pond,	0.10	4.54	.0017	.0158	.0020	0.83	.0005	.0000	0.23	0.7
Marlborough,	Lake Williams,	0.11	4.73	.0023	.0178	.0024	0.58	.0027	.0001	0.23	1.5
	Millham Brook Reservoir.	0.38	4.42	.0048	.0190	.0036	0.39	.0060	.0001	0.43	1.2
Maynard,	White Pond,	0.06	2.89	.0009	.0106	.0015	0.32	.0057	.0000	0.15	0.7
Milford,	Charles River, filtered,	0.19	3.54	.0011	.0061	–	0.31	.0102	.0000	–	0.9
Montague,	Lake Pleasant,	0.05	2.41	.0017	.0074	.0015	0.15	.0025	.0000	0.13	0.4
Nantucket,	Wannacomet Pond,	0.07	6.83	.0033	.0123	.0021	2.23	.0005	.0000	0.15	1.2
New Bedford,	Old Storage Reservoir,[1]	1.23	5.22	.0031	.0259	.0035	0.58	.0012	.0000	1.14	0.9
	Little Quittacas Pond,	0.26	4.01	.0033	.0190	.0027	0.58	.0002	.0000	0.39	0.7
	Great Quittacas Pond,	0.39	3.53	.0032	.0205	.0026	0.59	.0003	.0000	0.54	0.5
North Adams,	Notch Brook Reservoir,	0.04	7.46	.0025	.0071	.0019	0.08	.0012	.0001	0.10	6.1
	Broad Brook,	0.12	4.95	.0007	.0056	.0005	0.08	.0065	.0001	0.22	3.4
Northampton,	Middle Reservoir,	0.25	4.78	.0019	.0103	.0015	0.14	.0025	.0000	0.31	1.4
	Mountain Street Reservoir.	0.09	3.61	.0012	.0081	.0015	0.11	.0008	.0001	0.17	1.6
	West Brook,	0.11	4.24	.0009	.0058	.0006	0.14	.0040	.0001	0.16	1.7
North Andover,	Great Pond,	0.19	3.70	.0026	.0163	.0016	0.40	.0008	.0000	0.33	1.3
Northborough,	Lower Reservoir,	0.55	4.08	.0040	.0230	.0025	0.31	.0030	.0001	0.56	1.0
Northbridge,	Cook Allen Reservoir,	0.24	3.05	.0029	.0135	.0039	0.20	.0003	.0000	0.34	0.4
North Brookfield,	Doane Pond,	0.35	2.87	.0023	.0179	.0041	0.14	.0007	.0000	0.31	0.3
	North Pond,	0.42	2.08	.0039	.0335	.0130	0.17	.0007	.0001	0.53	0.3
Norwood,	Buckmaster Pond,	0.15	3.87	.0031	.0156	.0036	0.53	.0027	.0001	0.22	0.8
Orange,	Distributing Reservoir,	0.01	2.57	.0008	.0035	.0009	0.12	.0015	.0000	0.08	0.4
Palmer,	Lower Reservoir,	0.25	3.31	.0029	.0152	.0029	0.17	.0015	.0000	0.29	0.7
Peabody,	Brown's Pond,	0.16	3.32	.0016	.0138	.0027	0.75	.0097	.0001	0.26	1.0
	Spring Pond,	0.10	5.46	.0019	.0140	.0032	0.73	.0062	.0001	0.18	1.9
	Suntaug Lake,	0.06	4.00	.0014	.0160	.0031	0.74	.0012	.0001	0.16	2.0
Pittsfield,	Ashley Lake,	0.15	5.40	.0110	.0138	.0085	0.16	.0075	.0000	0.26	4.1

[1] Not used in 1908.

Averages of Chemical Analyses of Surface-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia.			Chlorine.	Nitrogen as		Oxygen Consumed.	Hardness.
				Free.	Albuminoid.			Nitrates.	Nitrites.		
					Total.	Sus-pended.					
Pittsfield,	Ashley Brook,	.15	4.65	.0029	.0103	.0017	0.13	.0065	.0000	.22	4.3
	Hathaway Brook,	.06	9.70	.0009	.0062	.0005	0.14	.0080	.0000	.13	8.2
	Mill Brook,	.11	4.47	.0010	.0072	.0003	0.10	.0045	.0000	.18	3.7
	Sacket Brook,	.11	6.25	.0017	.0075	.0020	0.12	.0150	.0000	.17	5.6
Plymouth,	Little South Pond,	.02	2.41	.0022	.0150	.0039	0.66	.0005	.0000	.12	0.1
	Great South Pond,	.01	3.06	.0015	.0137	.0027	0.66	.0003	.0000	.07	0.1
	Boot Pond,[1]	.02	2.59	.0016	.0163	.0054	0.63	.0005	.0000	.11	0.1
Randolph,	Great Pond,	.39	4.14	.0014	.0156	.0022	0.62	.0040	.0001	.46	0.8
Rockport,	Cape Pond,	.19	9.94	.0057	.0275	.0106	3.38	.0016	.0002	.35	1.6
Salem,	Wenham Lake,	.25	5.50	.0050	.0201	.0046	0.91	.0045	.0002	.40	2.0
	Longham Reservoir,	.76	7.08	.0098	.0327	.0115	1.05	.0082	.0004	.72	2.0
Southbridge,	Hatchet Brook Reservoir No. 3.	.28	2.86	.0027	.0237	.0073	0.18	.0009	.0000	.39	0.5
	Hatchet Brook Reservoir No. 4.	.53	3.43	.0116	.0292	.0095	0.19	.0007	.0001	.50	0.6
South Hadley,	Leaping Well Reservoir,	.12	3.02	.0038	.0303	.0129	0.19	.0032	.0002	.16	0.5
	Buttery Brook Reservoir.	.17	4.28	.0058	.0157	.0040	0.35	.0332	.0003	.16	0.8
Spencer,	Shaw Pond,	.10	2.65	.0009	.0124	.0012	0.18	.0027	.0000	.19	0.8
Springfield,	Ludlow Basin,	.22	2.59	.0016	.0139	.0035	0.16	.0011	.0000	.28	0.7
	Ludlow Canal,	.41	3.71	.0013	.0135	.0018	0.18	.0024	.0001	.46	1.0
	Ludlow Reservoir,	.28	2.84	.0011	.0185	.0056	0.16	.0004	.0000	.32	0.7
	Chapin Pond,[1]	.06	2.45	.0023	.0180	.0038	0.13	.0002	.0000	.20	0.3
	Five Mile Pond,[1]	.10	2.45	.0027	.0188	.0039	0.17	.0007	.0000	.22	0.3
	Loon Pond,[1]	.05	2.97	.0024	.0167	.0028	0.26	.0007	.0001	.15	0.7
	Borden Brook,[1]	.74	4.11	.0018	.0169	.0024	0.21	.0020	.0001	.80	1.0
	Pebble Brook,[1]	.48	3.47	.0015	.0183	.0044	0.15	.0010	.0001	.60	0.9
	Westfield Little River,[1]	.61	4.12	.0014	.0179	.0035	0.22	.0020	.0001	.71	1.1
Stockbridge,	Lake Averic,	.13	5.79	.0032	.0172	.0039	0.10	.0017	.0001	.26	4.3
Stoughton,	Muddy Brook,	.19	2.95	.0007	.0074	-	0.38	.0047	.0000	.20	0.6
Taunton,	Assawompsett Pond,	.31	3.32	.0017	.0164	.0029	0.55	.0008	.0000	.47	0.5
	Elder's Pond,	.12	3.03	.0010	.0148	.0025	0.52	.0008	.0000	.28	0.5
	Long Pond,	.58	3.41	.0012	.0152	.0014	0.54	.0005	.0000	.65	0.4
Wakefield,	Crystal Lake,	.22	5.15	.0025	.0211	.0048	0.69	.0053	.0001	.32	1.9
Wareham,	Jonathan's Pond,	.01	2.41	.0010	.0081	.0014	0.70	.0003	.0000	.08	0.0
Wayland,	Snake Brook Reservoir,	.52	4.85	.0039	.0167	.0019	0.36	.0085	.0001	.46	1.4

[1] Not used in 1908.

Averages of Chemical Analyses of Surface-water Sources, etc. — Concluded.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Suspended.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.
Westborough, .	Upper Sandra Pond, .	.24	2.73	.0021	.0180	.0044	0.23	.0018	.0000	.37	0.3
	Lower Sandra Pond, .	.03	2.88	.0010	.0082	.0012	0.24	.0007	.0002	.10	1.2
Westfield, . .	Montgomery Reservoir,	.42	2.32	.0049	.0205	.0053	0.14	.0012	.0000	.52	0.2
	Tekoa Reservoir, . .	.34	2.61	.0028	.0137	.0025	0.14	.0012	.0001	.40	0.2
	Tillotson Brook, . .	.11	3.07	.0036	.0075	.0028	0.17	.0022	.0001	.15	0.4
West Springfield, .	Darby Brook Reservoir,	.18	5.09	.0137	.0160	.0068	0.24	.0050	.0001	.24	2.4
	Bear Hole Brook, filtered.	.07	6.41	.0006	.0044	–	0.17	.0050	.0000	–	3.6
Weymouth, . .	Great Pond, ...	.70	4.22	.0025	.0158	.0019	0.57	.0028	.0000	.71	0.4
Williamsburg, .	Reservoir, ...	.18	3.54	.0026	.0076	.0007	0.14	.0015	.0001	.20	1.4
Winchester, . .	North Reservoir, . .	.09	4.07	.0018	.0188	.0067	0.47	.0005	.0001	.23	1.5
	South Reservoir, . .	.11	3.76	.0030	.0165	.0031	0.41	.0013	.0001	.22	1.1
	Middle Reservoir, .	.11	3.65	.0017	.0257	.0061	0.42	.0007	.0000	.27	1.2
Woburn, . . .	Horn Pond, . . .	.26	8.04	.0067	.0199	.0043	1.04	.0614	.0010	.37	3.3
Worcester, . .	Bottomly Reservoir, .	.24	3.76	.0030	.0165	.0039	0.24	.0098	.0001	.44	0.9
	Kent Reservoir, . .	.20	3.42	.0013	.0149	.0039	0.23	.0065	.0001	.34	1.0
	Leicester Reservoir, .	.20	3.25	.0029	.0124	.0020	0.23	.0087	.0001	.31	0.8
	Mann Reservoir, . .	.23	3.47	.0018	.0133	.0025	0.23	.0067	.0001	.37	1.0
	Upper Holden Reservoir.	.13	2.55	.0013	.0110	.0026	0.19	.0012	.0001	.23	0.3
	Lower Holden Reservoir.	.07	2.43	.0014	.0108	.0026	0.22	.0017	.0001	.20	0.5

Averages of Chemical Analyses of Ground-water Sources for the Year 1908.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Hardness.	Iron.
Adams, . . .	Tubular wells, . . .	.00	13.35	.0000	.0008	0.13	.0330	.0000	11.6	.0050
Amesbury, . .	Main Street wells, . .	.30	13.93	.0015	.0016	0.76	.0178	.0001	6.3	.2000
	Market Street wells, . .	.00	27.97	.0037	.0025	1.61	.0090	.0006	18.3	.0100
Attleborough, .	Well, ...	.02	4.22	.0004	.0034	0.40	.0118	.0000	1.9	.0048

Averages of Chemical Analyses of Ground-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Hardness.	Iron.
Avon,	Well,	.01	5.60	.0001	.0012	0.48	.0633	.0000	2.4	.0040
Ayer,	Large well,	.02	6.00	.0004	.0015	0.69	.0357	.0000	2.2	.0208
	Tubular wells,	.00	5.03	.0007	.0007	0.17	.0050	.0000	2.0	.0153
Billerica,	Tubular wells,	.13	6.48	.0012	.0028	0.31	.0056	.0000	2.2	.0362
Braintree,	Filter-gallery,	.05	6.19	.0023	.0052	1.03	.0503	.0000	2.0	.0087
Bridgewater,	Wells,	.17	8.47	.0008	.0021	0.47	.0101	.0000	3.2	.0682
Brookline,	Tubular wells and filter-gallery.	.14	8.85	.0044	.0053	0.61	.0217	.0000	4.7	.0208
Canton,	Springdale well,	.02	4.13	.0002	.0011	0.41	.0145	.0000	1.2	.0220
	Well near Henry's Spring,	.05	4.10	.0001	.0017	0.46	.0222	.0000	1.3	.0040
Chelmsford,	Wells,	.01	3.31	.0021	.0024	0.36	.0251	.0001	1.0	.0072
Cohasset,	Tubular wells No. 1,	.04	13.85	.0003	.0017	1.89	.0370	.0000	6.9	.0150
	Tubular wells No. 2,	.04	12.50	.0008	.0045	1.79	.1128	.0000	5.3	.0040
	Filter-gallery,	.29	13.10	.3680	.0142	1.31	.0840	.0020	6.7	.0500
Dedham,	Large well and tubular wells.	.01	10.60	.0005	.0019	0.94	.1683	.0000	4.3	.0043
Dracut,	Tubular wells,	.01	7.22	.0003	.0010	0.36	.0299	.0004	3.5	.0095
Dracut (Collinsville.	Tubular wells,	.02	4.60	.0003	.0014	0.28	.0117	.0000	1.9	.0103
Easton,	Well,	.00	4.13	.0001	.0013	0.55	.0430	.0000	1.6	.0060
Edgartown,	Tubular wells,	.00	2.76	.0001	.0009	0.89	.0031	.0009	0.2	.0032
Fairhaven,	Tubular wells,	.38	6.55	.0006	.0079	1.03	.0345	.0001	2.0	.0128
Foxborough,	Tubular wells,	.00	3.71	.0004	.0008	0.40	.0247	.0000	0.8	.0025
Framingham,	Filter-gallery,	.02	9.70	.0038	.0049	0.93	.0243	.0001	5.0	.0085
Grafton,	Filter-gallery,	.06	10.70	.0005	.0066	1.31	.2033	.0001	4.1	.0247
Groton,	Well,	.00	4.35	.0001	.0008	0.19	.0037	.0000	2.1	.0017
Hingham,	Wells,	.02	5.52	.0011	.0026	0.71	.0130	.0000	1.8	.0043
Hopkinton,	Tubular wells,	.00	15.27	.0000	.0017	1.48	.4367	.0000	6.6	.0013
Hyde Park,	Wells near Neponset River,	.13	14.34	.0210	.0047	2.14	.0638	.0002	6.0	.0769
	Wells near Mother Brook,	.11	9.11	.0004	.0051	1.00	.1846	.0000	3.7	.0048
Kingston,	Tubular wells,	.00	4.64	.0002	.0010	0.78	.0078	.0000	1.0	.0018
Leicester,	Wells,	.17	6.05	.0004	.0043	0.27	.0635	.0000	2.1	.0085
Lowell,	Boulevard wells (tubular),	.19	4.62	.0104	.0038	0.27	.0087	.0001	1.8	.0715
	Low-service Reservoir,	.14	4.86	.0054	.0058	0.31	.0239	.0001	1.9	.0342
Manchester,	Large well,	.00	11.93	.0002	.0007	1.90	1742	.0000	4.5	.0108
	Tubular wells,	.00	9.30	.0000	.0008	1.45	.1675	.0000	3.7	.0025
Mansfield,	Well,	.00	3.74	.0001	.0010	0.44	.0564	.0000	1.2	.0030

Averages of Chemical Analyses of Ground-water Sources, etc. — Continued.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia.		Chlorine.	Nitrogen as		Hardness.	Iron.
				Free.	Albuminoid.		Nitrates.	Nitrites.		
Marblehead,	Wells Nos. 1 and 2,	.10	23.72	.0120	.0022	4.60	.0140	.0003	9.5	.3441
	Well No. 2,	–	20.43	.0184	.0086	1.91	.0054	.0002	9.0	.4771
Marshfield,	Well,	.00	14.80	.0004	.0010	4.05	.1500	.0000	3.1	.0120
Medfield,	Spring,	.00	3.30	.0002	.0024	0.28	.0020	.0000	–	.0140
Merrimac,	Tubular wells,	.00	5.92	.0004	.0012	0.54	.0473	.0000	1.8	.0072
Methuen,	Tubular wells,	.15	7.36	.0009	.0047	0.37	.0151	.0000	2.9	.0619
Middleborough,	Well,	.17	5.97	.0028	.0051	0.64	.0508	.0000	2.3	.1349
Millbury,	Well,	.02	5.00	.0004	.0021	0.37	.0254	.0000	1.8	.0078
Millis,	Spring,	.00	7.60	.0010	.0014	0.70	.1600	.0000	3.0	.0010
Monson,	Well,	.00	3.30	.0001	.0009	0.14	.0113	.0000	1.0	.0033
Nantucket,	Wells,	.16	6.30	.0150	.0024	2.06	.0060	.0000	1.3	.0650
Natick,	Well,	.01	8.32	.0001	.0015	0.59	.0308	.0000	4.4	.0030
Needham,	Well No. 1,	.00	7.15	.0005	.0016	0.74	.1347	.0000	3.4	.0025
	Well No. 2,	.09	7.58	.0005	.0015	0.74	.1282	.0000	3.6	.0020
	Hick's Spring,[1]	.02	5.48	.0005	.0048	0.58	.0950	.0000	1.6	.0023
Newburyport,	Wells,	.06	14.29	.0010	.0028	3.19	.0362	.0000	4.9	.0533
Newton,	Tubular wells and filter-gallery.	.08	6.88	.0008	.0025	0.44	.0220	.0000	3.0	.0063
No. Attleborough,	Old well,	.01	6.84	.0002	.0012	0.68	.0520	.0000	3.1	.0030
	New well,	.00	3.60	.0000	.0012	0.33	.0020	.0000	2.0	.0020
Oak Bluffs,	Springs,	.01	4.39	.0007	.0012	1.07	.0115	.0000	0.5	.0129
Oxford,	Tubular wells,	.01	4.18	.0002	.0011	0.27	.0390	.0000	1.5	.0023
Provincetown,	Old wells,	–	9.54	.0152	.0184	2.46	.0024	.0006	4.0	.7900
	New wells,	.00	5.88	.0000	.0005	2.06	.0092	.0000	1.0	.0057
Reading,	Filter-gallery,	.48	8.95	.0106	.0100	0.99	.0026	.0000	2.9	.2625
	Filtered water,	.11	11.81	.0090	.0063	0.95	.0036	.0002	5.4	.0596
Scituate,	Wells,	.00	16.37	.0004	.0009	3.58	.1825	.0000	5.7	.0063
Sharon,	Well,	.00	10.25	.0002	.0010	1.29	.2108	.0000	4.4	.0028
Sheffield,	Spring,	.08	3.80	.0018	.0061	0.09	.0027	.0000	2.1	.0050
Shirley,	Well,	.00	2.07	.0002	.0005	0.16	.0035	.0000	0.2	.0018
Tisbury,	Well,	.00	4.15	.0001	.0005	1.01	.0029	.0000	0.4	.0068
Uxbridge,	Wells,	.00	4.63	.0004	.0010	0.48	.0765	.0000	1.3	.0028
Walpole,	Tubular wells,	.00	4.82	.0000	.0004	0.41	.0232	.0000	1.4	.0036
Waltham,	Old well,	.06	7.38	.0021	.0028	0.71	.0258	.0000	3.4	.0290

[1] Not used in 1908.

Averages of Chemical Analyses of Ground-water Sources, etc. — Concluded.

[Parts in 100,000.]

City or Town.	Source.	Color.	Residue on Evaporation.	Ammonia.		Chlorine.	Nitrogen as		Hardness.	Iron.
				Free.	Albu-minoid.		Nitrates.	Nitrites.		
Waltham,	New well,	.03	8.08	.0008	.0025	0.58	.0167	.0000	4.0	.0128
Ware,	Well,	.00	7.62	.0001	.0010	0.56	.2108	.0009	2.7	.0032
Wareham,	Wells,	.02	3.45	.0002	.0009	0.61	.0083	.0000	0.8	.0078
Webster,	Well,	.02	4.42	.0006	.0026	0.30	.0175	.0000	1.4	.0092
Wellesley,	Tubular wells,	.00	8.10	.0008	.0012	0.87	.1034	.0000	3.7	.0058
	Well at Williams Spring,	.00	11.62	.0011	.0017	1.13	.4242	.0000	4.4	.0063
Westford,	Wells,	.01	3.69	.0003	.0012	0.19	.0044	.0000	0.9	.0049
Weston,	Well,	.26	7.35	.0010	.0080	0.49	.0218	.0000	3.3	.0062
Winchendon,	Well,	.17	3.06	.0032	.0051	0.14	.0030	.0000	0.7	.0932
Woburn,	Filter-gallery,	.03	10.65	.0076	.0035	1.29	.0186	.0000	5.4	.0032
Wrentham,	Wells,	.00	2.70	.0003	.0013	0.28	.0033	.0000	0.7	.0034

SUMMARY

OF

WATER SUPPLY STATISTICS;

ALSO

RECORDS OF RAINFALL AND FLOW OF STREAMS.

WATER SUPPLY STATISTICS.

During the year 1908 water supplies were introduced into the towns of Marion (population, 1,029), Westford (population, 2,413) and Wrentham (population, 1,428), and into the Wareham Fire District. The village of Onset in the town of Wareham had been supplied previously.

Of the 354 cities and towns in Massachusetts all of the 33 cities and 155 of the towns are provided with public water supplies. The following table gives a classification by population of the cities and towns having and not having public water supplies: —

Population (1905).	Number of Places of Given Population having Public Water Supplies.	Total Population of Places in Preceding Column.	Number of Places of Given Population not having Public Water Supplies.	Total Population of Places in Preceding Column.
Under 500,	-	-	36	12,513
500-999,	4	3,755	50	36,782
1,000-1,499,	16	19,406	34	42,485
1,500-1,999,	13	23,445	22	38,584
2,000-2,499,	14	30,706	14	29,761
2,500-2,999,	13	35,009	2	5,517
3,000-3,499,	8	25,943	2	6,441
3,500-3,999,	5	18,931	3	11,394
Above 4,000,	115	2,648,521	3	14,537
Totals,	188	2,805,716	166	197,964

All of the towns, except Blackstone, having a population in excess of 5,000 are supplied with water, and there are only 10 towns in the State having a population in excess of 2,500 which are not provided with public water supplies. These towns are as follows: —

Town.	Population 1905.	Town.	Population 1905.
Blackstone,	5,786	Templeton,	3,783
Tewksbury,	4,415	Pepperell,[1]	3,268
Barnstable,	4,336	Sutton,	3,173
Dudley,	3,818	Westport,	2,867
Dartmouth,	3,793	Medway,	2,650

[1] Works under construction.

At the present time the water works are owned either by the municipality or by a fire or water supply district in all of the cities and 110 of the towns, while in 45 towns the works are owned by private companies. The following table gives a classification by population of the cities and towns which own their water works and those which are supplied with water by private companies: —

POPULATION (1905).	Number of Places of Given Population owning Water Works.	Total Population of Places in Preceding Column.	Number of Places of Given Population supplied with Water by Private Companies.	Total Population of Places in Preceding Column.
Under 1,000,	2	1,886	2	1,869
1,000-1,999,	20	30,767	9	12,064
2,000-2,999,	13	31,614	14	34,101
3,000-3,999,	7	24,219	6	20,655
4,000-4,999,	13	57,088	5	22,410
5,000-5,999,	12	65,487	2	10,365
6,000-6,999,	12	77,889	1	6,754
7,000-7,999,	7	50,508	3	22,929
Above 8,000,	57	2,297,476	3	37,615
Totals,	143	2,636,934	45	168,782

From the totals given in the above tables it will be seen that the population of the towns supplied with water by private companies is only 6.0 per cent. of the total population in all of the cities and towns supplied with water, and that there are now only 9 towns having a population above 5,000 which are supplied by private companies. These are Hyde Park,[1] Milford, Southbridge, Dedham, Palmer, Northbridge, Bridgewater, Amherst and Grafton.

CONSUMPTION OF WATER.

Records of the consumption of water are kept in nearly all of the cities and towns where water is pumped, and in several places supplied by gravity Venturi meters are used to measure the quantity supplied. A summary of these statistics for the year 1908 is given in the following table: —

[1] The town of Hyde Park voted early in January, 1906, to take the works of the Hyde Park Water Company.

Statistics relating to the Consumption of Water in Various Cities and Towns.

City or Town.	Estimated Population. 1908.	Average Daily Consumption (Gallons). 1908.	Daily Consumption per Inhabitant (Gallons). 1908.
Metropolitan water district: —	941,741	125,441,000	138
Arlington,	10,307	971,000	94
Belmont,	4,619	365,000	79
Boston,	616,073	98,379,000	160
Chelsea,	39,219	3,317,000	85
Everett,	31,976	2,636,000	82
Lexington,	4,949	329,000	66
Malden,	40,661	1,869,000	46
Medford,	20,551	2,069,000	101
Melrose,	15,095	1,352,000	90
Milton,	7,340	332,000	45
Nahant,	784	140,000	179
Quincy,	30,582	3,004,000	98
Revere,	14,017	1,293,000	92
Somerville,	73,849	6,589,000	89
Stoneham,	6,418	626,000	98
Swampscott,	5,497	509,000	93
Watertown,	12,189	732,000	60
Winthrop,	7,620	929,000	122
Abington and Rockland.	12,532	542,000	43
Andover,	6,523	513,000	79
Attleborough,	13,522	716,000	53
Avon,	1,997	118,000	59
Ayer,	2,350	119,000	51
Beverly,	16,026	1,736,000	108
Billerica,	2,884	108,000	37
Braintree,	7,418	424,000	57
Bridgewater and East Bridgewater.	10,578	208,000	20
Brockton,	52,438	2,026,000	39
Brookline,	25,537	2,353,000	92
Cambridge,	100,763	10,450,000	104
Canton,	4,778	280,000	59
Clinton,	12,768	536,000	42
Danvers and Middleton.	10,581	843,000	80
Dedham,	7,964	947,000	119
Easton,	4,952	128,000	26
Fall River,	106,301	4,968,000	47
Falmouth,	3,086	284,000	92
Foxborough,	3,423	163,000	48
Framingham,	11,696	572,000	49
Gardner,	12,731	960,000	75
Gloucester,	25,945	1,424,000	55
Groton,	2,374	80,000	34
Holliston,	2,702	39,000	14
Holyoke,	52,467	5,575,000	106
Hyde Park,	15,270	1,038,000	68
Ipswich,	5,533	220,000	40
Lancaster,	2,363	91,000	39
Lawrence,	74,545	3,425,000	46
Lincoln,	1,119	186,000	166
Lowell,	94,841	5,250,000	55
Lynn and Saugus,	89,114	6,118,000	68
Manchester,	2,676	251,000	94
Mansfield,	4,388	287,000	65
Marblehead,	6,985	750,000	107
Marlborough,	14,351	583,000	41
Maynard,	7,412	252,000	34
Merrimac,	1,736	99,000	57
Methuen,	9,374	388,000	41
Middleborough,	6,889	335,000	49
Milford and Hopedale.	14,567	865,000	59
Millbury,	4,734	159,000	34
Montague and Erving.	8,701	533,000	61
Nantucket,	2,884	198,000	69
Natick,	9,682	555,000	57
Needham,	4,445	355,000	80
New Bedford,	81,514	7,488,000	92
Newburyport,	14,793	956,000	65
Newton,	38,771	2,444,000	63
North Andover,	4,837	226,000	47

Statistics relating to the Consumption of Water in Various Cities and Towns — Concluded.

City or Town.	Estimated Population. 1908.	Average Daily Consumption (Gallons). 1908.	Daily Consumption per Inhabitant (Gallons). 1908.	City or Town.	Estimated Population. 1908.	Average Daily Consumption (Gallons). 1908.	Daily Consumption per Inhabitant (Gallons). 1908.
North Attleborough,	8,258	414,000	50	Stoughton, . .	6,269	196,000	31
North Brookfield, .	1,435	157,000	109	Taunton, . . .	30,926	2,247,000	73
Norwood, . . .	7,482	439,000	59	Wakefield, . .	10,855	730,000	67
Oak Bluffs, . .	1,161	174,000	150	Walpole, . . .	4,262	358,000	84
Orange, . . .	5,613	159,000	28	Waltham, . .	27,963	2,266,000	81
Peabody, . . .	14,043	2,333,000	166	Wareham,[1] . .	3,797	63,000	17
Plymouth, . .	12,035	1,229,000	102	Webster, . . .	10,746	359,000	33
Randolph and Holbrook.	6,736	358,000	53	Wellesley, . .	6,859	310,000	45
Reading, . . .	6,110	175,000	29	Westford, . .	2,286	35,000	15
Rockport, . .	4,360	297,000	68	Weston, . . .	2,245	77,000	34
Rutland, . . .	1,940	98,000	51	Whitman, . .	6,741	204,000	30
Salem, . . .	38,630	3,297,000	85	Winchendon, . .	6,492	137,000	21
Scituate, . . .	2,673	121,000	45	Woburn, . . .	14,491	1,652,000	114
Sharon, . . .	2,100	112,000	53	Worcester, . .	133,963	9,046,000	68
Shirley, . . .	1,699	36,000	21	Wrentham, . .	1,435	44,000	31

The estimated population given in the table is obtained by adding three-fifths of the increase in population from 1900 to 1905 to the population as determined by the census taken in the latter year. The daily consumption of water per inhabitant has been obtained by dividing the average daily consumption by the estimated total population of the city or town in 1908. The quantity obtained in this manner is somewhat less than the actual consumption per person using the water, because there are in all cities and towns a greater or less number of people who do not use the public supply. This difference is most marked in towns containing villages to which the public water supply has not been extended and in towns where the works have been in operation but a short time and where water has not come into general use. In some towns the population during the summer months is much greater than that which is shown by census returns, and in such cases the consumption per inhabitant as given in the table is higher than it would be if allowance were made for the increased population in the summer. With a few exceptions, however, the difference is not large.

[1] Including Wareham Fire District since May 1.

Rainfall.

The average rainfall in Massachusetts, as deduced from long-continued observations in various parts of the State, is 45.22 inches. The average rainfall for the year 1908 in these places was 37.61 inches, — an average deficiency of 7.61 inches. This deficiency is the greatest that has occurred since 1883. There was a slight excess of precipitation in the months of February, May and August, but in the remaining nine months there was a deficiency. The greatest excess in any one month occurred in August, when the rainfall was 5.34 inches, and the greatest deficiency occurred in November, when the rainfall was 1.13 inches.

The following table gives the normal rainfall in the State for each month, as deduced from observations at various places for a long period of years, together with the average rainfall at those places for each month during 1908 and the departure from the normal: —

Month.	Normal Rainfall (Inches).	Rainfall 1908 (Inches).	Excess or Deficiency 1908 (Inches).	Month.	Normal Rainfall (Inches).	Rainfall 1908 (Inches).	Excess or Deficiency 1908 (Inches).
January,	3.78	3.35	−0.43	August,	4.14	5.34	+1.20
February,	3.75	4.94	+1.19	September,	3.53	1.04	−2.49
March,	4.07	3.24	−0.83	October,	3.97	3.76	−0.21
April,	3.52	1.96	−1.56	November,	3.89	1.13	−2.76
May,	3.73	4.68	+0.95	December,	3.64	3.26	−0.38
June,	3.88	1.82	−2.06				
July,	3.82	3.59	−0.23	Total,	45.22	37.61	−7.61

An examination of the rainfall records of the State shows that in the late winter and spring months of 1908 the amount and distribution of the rainfall did not vary greatly from the normal. There was an excess in the months of February and May, and a slight deficiency in the months of January, March and April, so that at the end of May the accumulated deficiency for the State since the first of January was only 0.68 of an inch. The rainfall in June was fairly well distributed throughout the month, but the amount was small, being the least in any June since 1894. The rainfall in July, while slightly less than the normal, was not unusually low. The amount in the first half of the month was very small, but in the last half there were numerous showers, which greatly relieved the drought that had prevailed since the early part of June. The rainfall in August was above the normal, and with the exception of the years 1892 and 1898 was the greatest in any August since 1887. The greater part of the rainfall in that month occurred between the 4th and the 7th, during which time more than 2 inches fell over practically the whole State. The month of September, however, was a most unusual one, the rainfall in that month being

confined to four days, the 2d, 6th, 28th and 29th. With the exception of a trace recorded at Boston on the 11th, there is no record of any rainfall in Massachusetts between September 6 and 28, a period of twenty-two days. The greatest rainfall for the month recorded at any place in Massachusetts was 2.98 inches at Nantucket, and of that amount 2.1 inches fell in one storm, on the 2d of the month. The minimum monthly amount recorded at any place in the State was 0.34 of an inch at Lowell, and of that amount 0.27 of an inch fell on the 29th. The rainfall at Lowell in September was, with two exceptions, the smallest of any month since observations were begun at that place by the Proprietors of Locks and Canals, in 1855. The two exceptions were August, 1876, and September, 1877, when rainfalls of 0.27 and 0.25 of an inch, respectively, are recorded. At the end of September the average accumulated deficiency throughout the State since January 1 amounted to 4.26 inches. In October the rainfall was slightly below the normal, and was confined almost entirely to the last week, when it rained nearly every day. With the exception of a slight rainfall on the 11th there was no general rain between the 2d and the 25th. The rainfall in this month was much greater in the southeastern part than in the western part of the State. The rainfall in November was of frequent occurrence and well distributed throughout the month, but the amounts were small, and the total for the month was only 0.09 of an inch more than for the month of September. The rainfall in December was of frequent occurrence but generally small in amount, and the total for that month was slightly less than the normal.

The rainfall on the Sudbury River watershed during the year 1908 was 79 per cent. of the average, making that year the second in order of dryness in the past thirty-four years. The drier year was 1883, when the corresponding percentage was 75. The total rainfall on the Sudbury River watershed for the driest six months of the year 1908 was 13.64 inches, while the total rainfall for the driest six months of the year 1883 was 13.36 inches.

The total rainfall for the year 1908 was much greater in the eastern part of the State than in the western part, the average amount at Lowell, Chestnut Hill, Taunton and New Bedford being 39.89 inches, while the average amount at South Egremont, Williamstown, Amherst and Springfield was only 33.94 inches. The distribution of the rainfall throughout the year 1908 was such that by far the greater part of the deficiency, as compared with average years, occurred in the months of June, September and November, while in the remaining months the rainfall did not vary greatly from the normal. The effect of this distribution was to produce a drought which caused a heavy draught upon the ponds and reservoirs used as sources of water supply, thereby re-

ducing their level to a lower point than for many years. This drought was most severely felt in those cities and towns which derive their supply from large watersheds with comparatively small storage, and in several places the regular sources of supply were exhausted and temporary sources had to be obtained. This occurred almost entirely in the western portion of the State.

The following tables give the daily rainfall in inches for the year 1908 at ten places in different parts of Massachusetts: —

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected.

Day of Month.	January, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	-	-	-	-	-	-	-	-	-	-
2,	-	-	-	-	-	-	-	-	-	-
3,	0.05	-	-	-	-	-	-	-	-	-
4,	-	.02	0.06	0.03	0.08	0.08	0.07	-	0.07	0.10
5,	-	-	-	0.07	-	-	-	-	-	-
6,	-	-	-	-	-	-	-	-	-	-
7,	-	.13	0.74	-	0.82	0.55	1.34	-[1]	-	0.84
8,	0.63	-	0.08	1.17	-	0.15	-	1.85	1.33	0.04
9,	-	.02	0.02	0.07	0.01	-	-	-	-	-
10,	-	-	-	-	-	-	-	-	-	-
11,	-	-	-	-	-	-	-	-	-	-
12,	0.80	.16	0.66	0.52	0.57	0.50	1.23	-[1]	0.88	0.90
13,	-	.06	-	-	0.12	0.28	-	1.18	-	-
14,	-	.10	-	-	-	-	-	-	-	-
15,	0.06	-	-	-	-	-	-	-	-	-
16,	-	.01	-	-	0.04	-	-	0.02	-	0.05
17,	-	-	-	-	-	-	-	-	-	-
18,	-	-	-	-	-	-	-	-	-	-
19,	-	-	-	-	-	-	-	-	-	-
20,	-	-	-	-	-	-	-	-	-	-
21,	-	-	-	-	-	-	-	-	-	-
22,	-	-	0.01	-	-	-	-	-	-	-
23,	0.15	-	-	-	-	-	-	-	-	-
24,	0.10	-	0.06	0.97	0.26	0.22	0.34	0.70	0.65	1.70
25,	-	-	-	-	-	-	-	-	-	-
26,	1.28	-	0.03	0.21	-	-	-	-	-	-
27,	-	.42	0.53	-	0.27	0.27	0.22	0.54	0.65	0.33
28,	0.07	.02	-	-	-	-	-	-	-	-
29,	-	.01	0.04	0.21	0.02	0.14	-	0.21	0.16	0.20
30,	-	-	-	-	-	-	-	-	-	-
31,	0.18	-	-	-	-	-	-	-	-	-
Total,	3.32	.95	2.25	3.25	2.19	2.19	3.20	4.50	3.69	4.16

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	February, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	0.14	0.39	0.86	1.53	0.61	0.96	1.16	1.54	-	0.52
2,	0.51	-	-	-	0.04	-	-	-	0.88	-
3,	-	0.02	-	0.07	-	-	0.01	-	-	-
4,	0.11	-	-	-	-	-	-	-	-	-
5,	0.42	0.01	0.10	-	-	-	-	-	-	-
6,	0.06	0.31	0.38	0.97	0.26	0.30	0.62	0.54	0.26	0.55
7,	-	-	-	-	-	-	-	-	-	-
8,	-	-	-	-	-	-	-	-	-	-
9,	-	-	-	-	-	-	-	-	-	-
10,	-	-	-	-	-	-	-	-	-	-
11,	-	-	-	-	-	-	-	-	-	-
12,	-	-	-	-	-	-	0.21	-	-	-
13,	0.40	0.12	0.04	0.02	0.06	0.12	-	0.27	-	0.28
14,	0.18	0.14	0.16	-	-	-	-	-	-	0.06
15,	0.88	0.52	0.04	3.53	0.65	0.67	0.57	0.90	0.65	0.40
16,	-	-	-	-	-	-	-	-	-	-
17,	0.10	0.01	-	-	-	-	-	-	-	-
18,	-	-	-	-	-	-	-	-	-	-
19,	0.50	0.49	0.78	1.09	0.76	0.60	1.32	1.03	1.62	1.90
20,	-	-	-	-	-	0.30	-	0.90	-	.
21,	-	-	-	-	-	-	-	-	-	-
22,	-	0.02	-	-	-	-	-	-	-	-
23,	0.11	-	0.04	0.09	-	-	0.10	-	-	-
24,	-	-	-	-	0.04	0.09	-	0.11	0.16	0.10
25,	0.16	-	-	-	-	-	-	-	-	-
26,	0.33	0.26	1.18	0.37	0.96	0.91	0.97	-[1]	-	-
27,	-	-	-	0.68	-	0.15	-	0.93	0.76	0.85
28,	-	-	-	-	-	-	-	-	-	-
Total,	3.90	2.29	3.58	8.30	3.38	4.10	4.96	6.22	4.33	4.66

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	March, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	0.16	0.04	0.35	0.64	0.08	0.11	-	-[1]	-	-
2,	0.23	0.39	0.63	0.14	0.68	0.66	0.79	0.58	-	1.03
3,	-	-	-	-	-	-	-	0.38	1.14	-
4,	-	-	-	-	-	-	-	-	-	-
5,	-	-	-	-	-	-	-	-	-	-
6,	0.40	0.32	0.28	0.32	0.16	0.17	0.52	-[1]	-	0.33
7,	-	0.08	0.02	0.01	0.23	0.22	-	0.55	0.47	-
8,	0.08	-	0.08	0.09	0.01	-	-	-	-	-
9,	-	-	-	-	0.08	-	-	0.15	0.11	0.13
10,	-	-	-	-	-	-	-	-	-	-
11,	-	-	-	-	-	-	-	-	-	-
12,	-	-	-	-	-	-	-	-	-	-
13,	-	-	-	-	0.03	-	-	-	-	-
14,	-	0.06	-	-	-	-	-	0.21	0.09	0.17
15,	-	0.14	0.12	0.13	0.28	0.12	0.15	0.25	0.13	0.32
16,	-	0.08	-	-	0.01	0.02	0.02	-	0.16	0.02
17,	-	0.10	0.12	0.04	0.09	0.09	-[1]	0.20	0.15	0.07
18,	0.05	0.01	0.30	0.41	0.28	0.08	-[1]	-[1]	-	-
19,	0.56	0.06	0.30	0.04	0.62	0.23	0.52	0.88	1.29	0.91
20,	-	-	-	-	-	-	-	-	-	-
21,	-	-	-	-	-	-	-	-	-	-
22,	-	-	-	-	-	-	-	-	-	-
23,	-	0.21	0.31	0.24	0.19	0.15	0.24	-[1]	-	0.40
24,	0.38	0.24	0.02	-	-	0.06	-	0.20	0.33	-
25,	-	-	-	-	-	-	-	-	-	-
26,	-	-	-	-	-	-	-	-	-	-
27,	-	-	-	-	-	-	-	-	-	-
28,	-	0.17	0.05	-	0.08	0.07	-	-	-	-
29,	0.07	0.22	0.33	0.19	0.49	0.38	0.47	0.78	0.22	0.18
30,	0.21	-	-	-	-	-	-	-	-	-
31,	-	0.01	-	0.01	0.03	-	-	-	0.03	0.05
Total,	2.09	2.03	2.86	2.26	3.19	2.36	2.71	4.18	4.12	3.60

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	April, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	-	-	-	.02	-	-	-	-	-	-
2,	-	0.06	0.13	-	0.11	0.14	0.16	0.15	0.28	0.20
3,	-	-	-	-	-	-	-	0.04	-	-
4,	-	-	-	-	-	-	-	-	-	-
5,	0.05	-	0.09	.03	-	-	-	-	-	0.06
6,	-	0.11	0.22	-	0.17	0.17	0.16	0.14	0.10	-
7,	-	-	-	-	-	-	-	-	-	-
8,	0.94	0.30	0.61	.46	0.27	0.19	-	-	-	-
9,	-	0.44	0.05	-	0.31	0.42	0.52	0.51	0.63	0.52
10,	-	-	0.01	.02	0.02	-	-	0.06	-	0.13
11,	0.15	-	-	-	0.04	-	-	-	0.14	-
12,	-	0.05	-	-	-	-	-	-	-	-
13,	-	0.14	0.01	-	-	0.01	0.06	-	-	-
14,	-	-	-	-	-	-	-	0.03	-	-
15,	0.20	0.27	0.38	.04	0.35	0.28	0.24	0.31	0.24	0.14
16,	-	-	-	-	-	0.01	-	-	-	-
17,	-	-	-	-	-	-	-	-	-	-
18,	0.30	0.09	0.06	.19	0.30	0.15	0.34	0.40	-	-
19,	0.09	0.35	0.08	-	-	0.19	-	0.08	0.35	0.48
20,	0.27	0.07	0.01	.02	-	-	-	0.04	-	0.07
21,	0.13	-	-	-	-	-	-	-	0.09	-
22,	-	-	-	-	-	-	-	-	-	-
23,	0.12	-	-	.01	-	-	-	-	-	-
24,	-	-	-	-	-	-	-	-	-	-
25,	0.24	0.05	0.06	-	-	-	0.04	-	-	0.14
26,	-	0.29	-	-	-	0.01	-	0.09	0.20	-
27,	0.05	-	-	-	-	-	-	-	-	-
28,	0.12	0.60	0.12	-	0.09	0.04	0.06	0.06	0.14	0.01
29,	-	-	-	-	-	-	-	-	-	-
30,	-	0.03	0.22	-	-	-	0.35	0.78	0.61	-
Total,	2.66	2.85	1.97	.79	1.66	1.61	1.95	2.64	2.78	1.75

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	May, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	0.78	0.32	-	0.42	0.65	0.75	0.18	-	0.25	0.86
2,	0.18	0.11	0.68	-	0.13	0.08	-	-	0.09	0.09
3,	-	0.04	-	0.16	-	0.17	-	-	-	-
4,	-	-	-	-	0.02	-	-	-	-	-
5,	-	-	-	-	-	-	-	-	-	-
6,	0.05	-	0.02	-	-	-	-	-	-	-
7,	1.15	1.16	1.16	1.64	1.04	0.45	-[1]	-[1]	-	-
8,	0.55	0.57	0.22	0.02	-	0.82	1.66	2.36	1.46	2.36
9,	0.30	0.77	0.16	0.03	0.16	0.11	0.05	0.07	0.13	0.03
10,	-	0.01	-	-	-	-	-	-	-	-
11,	-	-	-	-	-	-	-	-	-	-
12,	0.02	-	-	-	0.13	-	-	-	-	-
13,	-	-	-	-	-	-	-	-	-	-
14,	0.33	0.63	0.39	0.21	0.28	0.57	0.50	0.30	0.21	0.05
15,	-	-	-	-	-	-	-	-	-	-
16,	-	-	-	-	-	-	-	-	-	-
17,	-	-	-	-	-	-	-	-	-	-
18,	-	-	-	-	-	-	-	-	-	-
19,	0.03	-	-	-	-	-	-	-	-	-
20,	0.07	0.08	0.08	-	-	-	-	-	-	-
21,	0.34	0.19	0.23	0.68	0.14	0.19	0.65	0.10	0.13	0.09
22,	0.08	0.46	0.32	0.50	0.24	0.15	-	0.09	-	-
23,	-	-	0.02	-	0.11	0.01	-	-	0.35	0.09
24,	-	-	-	-	-	-	-	-	-	-
25,	-	-	-	-	-	-	-	-	-	-
26,	-	-	0.05	-	0.02	-	-	-	-	-
27,	-	-	-	0.18	-	0.04	0.06	0.02	-	-
28,	-	-	-	-	-	-	-	-	-	-
29,	-	-	-	-	-	-	-	-	-	0.03
30,	0.67	0.46	0.99	1.68	1.85	1.05	1.08	1.30	0.83	-
31,	0.03	0.44	0.03	-	0.06	0.88	-	0.32	-	0.42
Total,	4.56	5.19	4.35	5.52	4.83	5.22	4.18	4.56	3.45	4.02

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	June, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	0.02	0.08	-	0.02	0.01	0.06	.06	-	-	-
2,	-	-	-	-	-	-	-	-	-	-
3,	-	-	-	-	-	-	-	-	-	-
4,	-	-	-	-	-	-	-	-	-	-
5,	-	-	-	-	-	-	-	-	-	-
6,	-	-	-	-	-	-	-	-	-	-
7,	-	-	-	-	-	-	-	-	-	-
8,	-	-	-	-	-	-	-	-	-	-
9,	-	-	-	-	-	-	-	-	-	-
10,	-	0.05	-	-	-	-	-	-	-	-
11,	-	-	-	-	-	-	-	-	0.17	-
12,	-	-	-	-	-	-	-	-	-	0.25
13,	-	-	-	-	-	-	-	-	-	-
14,	-	-	-	-	-	-	-	-	-	-
15,	-	0.72	.28	0.51	-	-	-	-	-	-
16,	-	0.57	.18	-	0.48	0.56	.51	0.78	1.34	0.84
17,	-	-	-	-	-	-	-	-	-	-
18,	-	-	-	-	-	-	-	-	-	-
19,	-	-	-	-	-	-	-	-	-	-
20,	-	0.56	-	-	-	-	-	-	-	-
21,	-	-	-	-	-	-	-	-	-	-
22,	-	-	-	-	-	-	-	-	-	-
23,	0.45	-	-	0.17	0.20	-	.03	-	0.16	0.43
24,	1.28	-[1]	.28	1.69	0.41	0.25	.25	0.29	0.45	0.12
25,	-	1.25	-	-	-	0.19	-	-	-	-
26,	-	-	-	-	-	-	-	-	-	-
27,	-	-	-	-	-	-	-	-	-	-
28,	-	-	-	-	-	0.05	-	-	-	-
29,	0.14	0.01	.07	0.01	0.02	0.04	.08	0.16	0.20	-
30,	-	-	-	-	-	-	-	0.05	-	-
Total,	1.89	3.24	.76	2.40	1.12	1.15	.93	1.28	2.32	1.69

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	July, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	-	-	-	-	-	-	-	-	0.06	-
2,	0.50	0.21	0.43	1.72	0.04	0.08	-	-	-	-
3,	0.88	0.40	0.08	0.14	0.09	0.48	0.15	-	0.05	-
4,	0.20	0.01	0.01	-	0.12	0.61	0.04	0.51	-	-
5,	-	0.04	-	-	-	-	-	-	-	-
6,	-	-	0.01	-	-	-	-	-	-	-
7,	-	0.14	-	-	-	-	-	-	-	-
8,	-	-	-	-	-	-	-	-	-	-
9,	-	-	-	-	-	-	-	-	-	-
10,	-	-	-	-	-	-	-	-	-	-
11,	-	-	-	-	-	-	-	-	-	-
12,	0.17	-	0.01	-	0.06	0.09	-	-	-	-
13,	-	-	-	-	-	-	-	-	-	0.45
14,	1.08	0.28	0.42	0.68	0.84	0.13	0.26	0.14	0.27	-
15,	-	0.63	0.04	-	0.05	0.08	-	0.05	-	-
16,	-	-	-	-	-	-	-	-	-	-
17,	0.02	0.06	0.12	-	-	0.07	0.19	-	-	-
18,	0.09	0.66	0.85	0.05	1.08	0.15	0.13	0.11	-	0.05
19,	-	0.08	-	0.04	-	0.36	0.49	0.88	1.00	0.20
20,	-	-	-	-	-	-	-	0.19	-	-
21,	0.44	-	-	-	-	-	-	-	-	-
22,	0.01	1.66	0.08	0.02	0.61	1.14	0.61	0.84	1.45	0.22
23,	-	-	0.01	-	-	-	-	0.03	0.30	0.24
24,	1.30	0.04	-	-	0.20	-	-	0.04	-	-
25,	0.73	1.45	1.22	1.34	1.22	1.20	-[1]	-[1]	0.92	0.86
26,	-	-	-	-	-	0.06	1.17	1.94	-	-
27,	-	-	-	-	-	-	-	-	-	-
28,	-	-	-	-	-	-	-	-	-	-
29,	-	-	-	-	0.05	-	-	-	-	-
30,	-	-	-	-	-	-	-	-	-	-
31,	-	-	-	-	-	-	-	-	-	-
Total,	5.32	4.98	3.28	3.99	4.36	4.40	3.04	4.18	4.05	2.02

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	August, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1, ...	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-
4, ...	-	-	-	-	0.19	0.19	0.12	0.29	0.23	0.23
5, ...	1.56	1.92	0.47	1.82	1.42	1.91	-	0.38	-	0.74
6, ...	0.40	-	0.48	1.79	0.87	1.03	0.78	0.45	0.83	-
7, ...	0.36	0.06	0.11	0.39	1.83	0.43	0.73	1.84	0.04	0.75
8, ...	-	0.08	-	-	-	-	0.53	-	-	-
9, ...	-	-	-	-	-	-	-	-	-	0.06
10, ...	-	-	0.79	-	0.08	-	-	0.03	-	-
11, ...	0.90	-	-	0.80	0.05	1.37	0.12	0.10	-	-
12, ...	-	-	-	-	-	-	-	-	-	-
13, ...	0.10	0.08	0.22	-	0.93	0.35	0.33	0.08	-	-
14, ...	-	-	-	0.07	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-
16, ...	0.27	-	-	-	-	-	-	-	-	-
17, ...	0.08	0.83	1.02	0.47	0.37	0.45	0.36	0.36	-	0.32
18, ...	-	0.25	-	-	-	0.22	-	-	0.07	-
19, ...	-	-	-	-	-	-	-	-	-	0.04
20, ...	-	-	-	-	-	-	-	-	-	-
21, ...	0.31	0.40	0.39	-	0.38	0.34	-	-	-	-
22, ...	-	-	-	0.43	-	-	0.34	0.38	1.04	1.85
23, ...	-	-	-	-	-	-	-	-	-	-
24, ...	-	-	-	-	-	-	-	-	-	-
25, ...	-	-	-	-	-	-	-	-	-	-
26, ...	0.49	0.82	0.79	0.93	0.96	1.08	0.98	-[1]	-	-
27, ...	0.25	-	-	-	-	-	-	1.70	2.46	1.30
28, ...	-	-	-	-	-	-	-	-	-	-
29, ...	-	-	-	-	-	-	-	-	-	-
30, ...	-	-	-	-	-	-	-	-	-	-
31, ...	-	-	-	-	-	-	-	-	-	-
Total, . .	4.72	3.91	4.27	6.70	7.08	7.32	4.29	5.56	4.67	5.29

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	September, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	-	-	-	-	-	-	-	-	-	-
2,	-	-	0.30	-	0.01	-	-	-	0.58	0.72
3,	-	-	-	-	-	-	-	-	-	-
4,	-	-	-	-	-	-	-	-	-	-
5,	-	-	-	-	-	-	-	-	-	-
6,	-	-	0.09	-	0.32	0.02	.07	0.13	0.22	0.25
7,	-	-	-	-	-	-	-	-	-	-
8,	-	-	-	-	-	-	-	-	-	-
9,	-	-	-	-	-	-	-	-	-	-
10,	-	-	-	-	-	-	-	-	-	-
11,	-	-	-	-	-	-	-	-	-	-
12,	-	-	-	-	-	-	-	-	-	-
13,	-	-	-	-	-	-	-	-	-	-
14,	-	-	-	-	-	-	-	-	-	-
15,	-	-	-	-	-	-	-	-	-	-
16,	-	-	-	-	-	-	-	-	-	-
17,	-	-	-	-	-	-	-	-	-	-
18,	-	-	-	-	-	-	-	-	-	-
19,	-	-	-	-	-	-	-	-	-	-
20,	-	-	-	-	-	-	-	-	-	-
21,	-	-	-	-	-	-	-	-	-	-
22,	-	-	-	-	-	-	-	-	-	-
23,	-	-	-	-	-	-	-	-	-	-
24,	-	-	-	-	-	-	-	-	-	-
25,	-	-	-	-	-	-	-	-	-	-
26,	-	-	-	-	-	-	-	-	-	-
27,	-	-	-	-	-	-	-	-	-	-
28,	1.30	.04	0.11	-	0.04	-	-	1.09	-	-
29,	-	.34	1.23	.74	0.87	1.04	.27	-	0.37	0.30
30,	-	-	-	-	-	-	-	-	-	-
Total,	1.30	.38	1.73	.74	1.24	1.06	.34	1.22	1.17	1.27

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
	October, 1908.									
1,	0.23	-	-	-	-	-	-	-	-	-
2,	0.04	0.31	0.17	0.04	0.09	0.13	0.23	0.68	2.04	2.37
3,	-	-	-	-	-	-	-	-	-	-
4,	-	-	-	-	-	-	-	-	-	-
5,	-	-	-	-	-	-	-	-	-	-
6,	-	-	-	-	-	-	-	-	-	-
7,	-	-	-	-	-	-	-	-	-	-
8,	-	-	-	-	-	-	-	-	-	-
9,	-	-	-	-	-	-	-	-	0.05	0.10
10,	0.12	-	-	-	-	-	-	-	-	-
11,	0.10	0.28	0.34	0.25	0.16	0.53	-	0.20	0.16	0.12
12,	-	-	-	-	-	-	0.33	-	-	-
13,	-	-	-	-	-	-	-	-	-	-
14,	-	-	-	-	-	-	-	-	-	-
15,	-	-	-	-	-	-	-	-	-	-
16,	-	-	-	-	-	-	-	-	-	-
17,	-	-	-	-	-	-	-	-	-	-
18,	-	-	-	-	-	-	-	-	-	-
19,	-	-	-	-	-	-	-	-	-	-
20,	-	-	-	-	-	-	-	-	-	-
21,	-	-	-	-	-	-	-	-	-	-
22,	-	-	-	-	-	-	-	-	-	-
23,	-	-	-	-	-	-	-	-	-	-
24,	0.05	-	-	-	-	-	-	-	-	-
25,	0.02	-	-	0.03	0.05	-	-	-	-	0.03
26,	0.88	0.37	0.40	1.01	0.28	0.30	- [1]	1.42	1.24	2.88
27,	0.15	0.02	-	-	-	0.03	0.67	-	-	-
28,	0.41	0.47	0.53	0.54	0.58	0.35	-	0.20	-	-
29,	0.04	0.29	0.07	0.05	0.15	0.29	- [1]	1.60	-	-
30,	-	-	0.06	0.49	0.42	0.27	1.34	0.24	2.13	2.04
31,	-	-	-	-	-	-	-	-	-	-
Total,	2.04	1.74	1.57	2.41	1.73	1.90	2.57	4.34	5.62	7.54

[1] Amount included in that of following day.

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Continued.

Day of Month.	November, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1, ...	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-
4, ...	-	.16	-	-	-	-	-	-	-	-
5, ...	-	.02	-	-	-	-	-	-	-	-
6, ...	.09	.01	-	-	-	-	-	-	-	-
7, ...	-	.04	-	-	-	-	-	-	-	-
8, ...	-	.01	0.02	-	.18	.04	0.13	0.04	0.18	0.22
9, ...	-	-	-	-	-	-	-	-	-	-
10, ...	-	-	-	-	-	-	-	0.02	-	-
11, ...	.15	.19	0.19	.09	.17	.19	0.11	0.16	-	0.12
12, ...	-	-	-	-	-	-	-	-	0.15	-
13, ...	-	-	-	-	-	-	-	-	-	-
14, ...	.35	-	0.56	-	.05	-	-	0.65	-	-
15, ...	-	.25	0.02	.49	.41	.54	0.55	-	0.59	0.68
16, ...	-	-	-	-	-	-	-	-	-	-
17, ...	-	-	-	-	-	-	-	-	-	-
18, ...	.15	.06	0.22	.09	.07	.05	0.10	0.08	0.23	0.30
19, ...	-	.02	-	-	-	-	-	0.10	-	-
20, ...	-	.06	-	-	-	.04	0.25	-	-	0.05
21, ...	-	-	-	-	-	-	-	-	-	-
22, ...	-	-	-	-	-	-	-	-	-	-
23, ...	-	-	-	-	-	-	-	-	-	-
24, ...	-	-	-	-	-	-	-	-	-	-
25, ...	.01	.01	0.01	-	.01	.04	-	-	-	-
26, ...	-	-	0.03	.02	.01	.03	-	0.10	0.12	-
27, ...	-	-	-	-	.03	-	-	-	-	0.08
28, ...	-	-	-	-	-	-	-	-	-	-
29, ...	-	-	-	-	-	-	-	-	-	-
30, ...	-	-	0.01	-	-	-	-	0.02	0.05	-
Total, . .	.75	.83	1.06	.69	.93	.93	1.14	1.17	1.32	1.45

Daily Rainfall, in Inches, at Ten Places in Massachusetts, Geographically Selected — Concluded.

Day of Month.	December, 1908.									
	South Egremont.	Williamstown.	Amherst.	Springfield.	Worcester.	Fitchburg.	Lowell.	Chestnut Hill (Boston).	Taunton.	New Bedford.
1,	-	-	-	-	-	-	-	-	0.04	-
2,	-	0.04	-	-	-	-	-	-	-	-
3,	-	-	-	-	-	-	-	-	-	-
4,	-	0.02	-	0.02	0.09	-	0.04	0.16	-	-
5,	-	-	-	-	-	0.04	-	-	-	0.17
6,	0.10	-	-	-	-	-	-	-	-	-
7,	0.06	0.94	1.68	1.74	1.44	1.60	1.46	1.50	2.15	2.00
8,	0.40	-	-	-	-	-	-	-	-	-
9,	0.38	0.01	-	-	-	-	-	-	-	-
10,	0.05	-	-	-	-	-	-	-	-	-
11,	-	0.30	0.22	-	0.22	0.33	-[1]	0.78	-	-
12,	0.44	0.09	0.18	0.38	0.15	0.23	0.62	0.21	1.11	1.13
13,	0.06	0.02	0.06	-	0.04	0.05	-	-	-	0.05
14,	0.11	-	-	-	-	-	-	-	-	-
15,	0.22	0.21	0.10	-	0.13	-	0.04	0.16	-	0.02
16,	-	-	-	-	-	-	-	-	-	-
17,	-	-	-	-	-	-	-	-	-	-
18,	0.23	0.08	0.35	-	0.16	0.28	0.50	0.17	0.25	0.18
19,	0.26	-	-	-	-	-	-	-	-	-
20,	-	0.01	-	-	-	-	-	-	-	-
21,	-	-	-	-	-	-	-	-	-	-
22,	-	-	-	-	-	-	-	-	-	-
23,	-	-	-	-	-	-	-	-	-	-
24,	0.07	-	-	-	-	-	-	-	-	-
25,	-	0.07	0.01	-	0.01	-	-	-	-	-
26,	-	-	-	-	-	-	-	-	-	0.03
27,	-	-	-	-	-	-	-	-	-	-
28,	-	-	-	-	-	-	-	-	-	-
29,	-	-	-	-	-	-	-	-	-	-
30,	0.44	0.30	-[1]	-	0.06	-	0.37	-[1]	-	-
31,	-	-	0.45	0.06	0.32	0.29	-	0.53	0.95	0.85
Total,	2.82	2.09	3.05	2.17	2.62	2.82	3.03	3.46	4.50	4.43
Totals for year,	35.39	30.48	30.68	39.22	34.28	35.06	32.34	43.31	42.02	41.88

[1] Amount included in that of following day.

Flow of Streams.

Sudbury River.

The flow of the Sudbury River during the year 1908 was 66 per cent. of the normal, making the year the third in order of dryness in the past thirty-four years. The drier years were 1880 and 1883, when the corresponding percentages were 55 and 50, respectively. The flow during the month of January was in excess of the normal, but during the remaining eleven months of the year it was less than the normal, the greatest deficiencies occurring in the months of April and December. During the months of July and September the flow was less than the evaporation from the water surfaces of the reservoirs, so that the flow is represented by a minus quantity. The average flow for the driest six months, July to December, inclusive, was 44,000 gallons per day per square mile, or 10 per cent. of the normal flow and 47 per cent. of the minimum flow ever before recorded for a similar period during the past thirty-four years.

In order to show the relation between the flow of the Sudbury River during each month of the year 1908 and the normal flow of that stream, as deduced from observations during thirty-four years, from 1875 to 1908, inclusive, the following table has been prepared. The area of the watershed of the Sudbury River above the point of measurement is 75.2 square miles.

Table showing the Average Monthly Flow of the Sudbury River for the Year 1908, in Cubic Feet per Second per Square Mile of Drainage Area, and in Million Gallons per Day per Square Mile of Drainage Area; also, Departure from the Normal Flow.

Month.	Normal Flow.		Actual Flow in 1908.		Excess or Deficiency.	
	Cubic Feet per Second per Square Mile.	Million Gallons per Day per Square Mile.	Cubic Feet per Second per Square Mile.	Million Gallons per Day per Square Mile.	Cubic Feet per Second per Square Mile.	Million Gallons per Day per Square Mile.
January,	1.926	1.245	2.978	1.925	+1.052	+.680
February,	2.702	1.746	2.377	1.536	−0.325	−.210
March,	4.479	2.894	3.492	2.257	−0.987	−.637
April,	3.176	2.053	1.729	1.117	−1.447	−.936
May,	1.708	1.104	1.618	1.046	−0.090	−.058
June,	0.810	0.523	0.301	0.194	−0.509	−.329
July,	0.290	0.187	−0.022	−0.014	−0.312	−.201
August,	0.410	0.265	0.157	0.102	−0.253	−.163
September,	0.404	0.261	−0.127	−0.082	−0.531	−.343
October,	0.748	0.483	0.072	0.047	−0.676	−.436
November,	1.315	0.850	0.110	0.071	−1.205	−.779
December,	1.647	1.064	0.210	0.136	−1.437	−.928
Average for whole year,	1.629	1.053	1.074	0.694	−0.555	−.359

The following table gives the rainfall upon the Sudbury River watershed and the total yield, expressed in inches in depth on the watershed (inches of rainfall collected), for each year of the past thirty-four years, from 1875 to 1908, inclusive, together with the average for that period: —

Rainfall, in Inches, received and collected on the Sudbury River Watershed.

Month.	1875.			1876.			1877.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	2.42	0.184	7.6	1.83	1.147	62.7	3.22	1.174	36.5
February,	3.15	2.411	76.5	4.21	2.282	54.2	0.74	1.529	206.9
March,	3.74	2.862	76.5	7.43	7.911	106.5	8.36	8.586	102.7
April,	3.23	5.263	162.9	4.20	5.683	135.4	3.43	4.132	120.3
May,	3.56	2.119	59.5	2.76	2.031	73.5	3.70	2.482	67.0
June,	6.24	1.501	24.0	2.04	0.383	18.8	2.43	1.031	42.5
July,	3.57	0.573	16.0	9.13	0.326	3.6	2.95	0.360	12.2
August,	5.53	0.706	12.8	1.72	0.723	42.0	3.68	0.216	5.9
September,	3.43	0.358	10.4	4.62	0.318	6.9	0.32	0.103	31.9
October,	4.85	1.152	23.8	2.24	0.417	18.6	8.52	1.127	13.2
November,	4.83	2.248	46.5	5.76	1.878	32.6	5.80	2.447	42.2
December,	0.94	1.041	110.7	3.62	0.809	22.3	0.87	2.300	264.4
Totals and averages,	45.49	20.418	44.9	49.56	23.908	48.2	44.02	25.487	57.9

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1878.			1879.			1880.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	5.63	3.228	57.3	2.48	1.249	50.4	3.57	2.000	56.0
February,	5.97	3.972	66.5	3.56	2.756	77.4	3.98	2.982	74.9
March,	4.69	6.256	133.4	5.14	4.156	80.9	3.31	2.451	73.9
April,	5.79	2.807	48.5	4.72	5.379	114.1	3.11	2.017	65.0
May,	0.96	2.487	260.2	1.58	1.987	125.8	1.84	0.917	50.0
June,	3.88	0.873	22.5	3.79	0.713	18.8	2.14	0.303	14.2
July,	2.97	0.229	7.7	3.93	0.281	7.1	6.27	0.315	5.0
August,	6.94	0.848	12.2	6.51	0.705	10.8	4.01	0.212	5.3
September,	1.29	0.277	21.5	1.88	0.243	12.9	1.60	0.138	8.6
October,	6.42	0.921	14.3	0.81	0.126	15.6	3.74	0.181	4.8
November,	7.02	2.922	41.6	2.68	0.355	13.2	1.78	0.354	19.9
December,	6.37	5.667	89.0	4.34	0.825	19.0	2.83	0.312	11.0
Totals and averages,	57.98	30.487	52.6	41.42	18.775	45.3	38.18	12.182	31.9

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1881.			1882.			1883.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	5.56	0.740	13.3	5.95	2.213	37.2	2.81	0.597	21.2
February,	4.65	2.491	53.6	4.55	3.872	85.2	3.87	1.664	43.0
March,	5.73	7.142	124.6	2.65	5.064	191.2	1.78	2.873	161.4
April,	2.00	2.669	133.4	1.82	1.497	82.1	1.84	2.330	126.3
May,	3.51	1.721	49.0	5.07	2.304	45.5	4.19	1.673	40.0
June,	5.39	2.309	42.8	1.66	0.913	54.9	2.40	0.518	21.6
July,	2.35	0.493	21.0	1.77	0.154	8.7	2.68	0.206	7.7
August,	1.36	0.264	19.4	1.67	0.099	5.9	0.73	0.140	19.1
September,	2.62	0.340	13.0	8.74	0.529	6.0	1.52	0.157	10.4
October,	2.95	0.331	11.2	2.07	0.534	25.7	5.60	0.331	5.9
November,	4.09	0.682	16.7	1.15	0.362	31.5	1.81	0.354	19.5
December,	3.96	1.383	34.9	2.30	0.561	24.5	3.55	0.345	9.7
Totals and averages,	44.17	20.565	46.6	39.40	18.102	45.9	32.78	11.188	34.1

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1884.			1885.			1886.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	5.09	1.775	34.9	4.71	2.203	46.8	6.36	2.606	40.9
February,	6.54	4.742	72.5	3.87	2.182	56.4	6.28	7.734	123.2
March,	4.72	6.752	143.1	1.07	2.805	262.1	3.61	3.672	101.7
April,	4.41	4.925	111.8	3.60	3.133	86.9	2.22	3.361	151.1
May,	3.47	1.838	53.0	3.48	2.383	68.4	3.00	1.285	42.9
June,	3.44	0.719	20.9	2.87	0.735	25.7	1.47	0.350	23.9
July,	3.67	0.399	10.9	1.43	0.111	7.8	3.27	0.206	6.3
August,	4.65	0.458	9.8	7.18	0.429	6.0	4.10	0.168	4.1
September,	0.85	0.076	8.9	1.43	0.209	14.7	2.90	0.203	7.0
October,	2.48	0.148	6.0	5.09	0.599	11.8	3.24	0.260	8.0
November,	2.65	0.302	11.4	6.09	2.033	33.3	4.64	1.161	25.0
December,	5.17	1.650	31.9	2.72	2.094	77.0	4.97	1.819	36.6
Totals and averages,	47.14	23.784	50.5	43.54	18.916	43.4	46.06	22.325	49.5

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1887. Rainfall.	1887. Rainfall collected.	1887. Per Cent. collected.	1888. Rainfall.	1888. Rainfall collected.	1888. Per Cent. collected.	1889. Rainfall.	1889. Rainfall collected.	1889. Per Cent. collected.
January, ...	5.20	4.619	88.8	4.15	1.878	45.3	5.37	4.963	92.4
February, . . .	4.78	4.558	95.3	3.68	3.255	88.3	1.65	1.926	116.4
March, ...	4.90	5.116	104.4	6.02	5.775	95.9	2.37	2.388	100.9
April, ...	4.27	4.522	106.0	2.43	4.566	188.3	3.41	2.434	71.4
May, ...	1.16	1.799	154.5	4.82	2.912	60.3	2.95	1.569	53.3
June, ...	2.65	0.714	26.9	2.54	0.728	28.7	2.80	1.128	40.3
July, ...	3.76	0.204	5.5	1.41	0.209	14.9	8.94	1.130	12.6
August, ...	5.28	0.382	7.2	6.22	0.677	10.9	4.18	2.554	61.2
September, . . .	1.32	0.191	14.5	8.59	1.994	23.2	4.60	1.422	30.9
October, ...	2.83	0.339	12.0	4.99	3.566	71.4	4.25	2.194	51.6
November, . . .	2.67	0.636	23.8	7.22	4.761	65.9	6.29	3.351	53.3
December, . . .	3.88	1.147	29.6	5.40	5.428	100.6	3.14	3.997	127.3
Totals and averages,	42.70	24.227	56.7	57.47	35.749	62.2	49.95	29.056	58.2

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1890. Rainfall.	1890. Rainfall collected.	1890. Per Cent. collected.	1891. Rainfall.	1891. Rainfall collected.	1891. Per Cent. collected.	1892. Rainfall.	1892. Rainfall collected.	1892. Per Cent. collected.
January, ...	2.53	2.237	88.4	7.02	5.383	76.7	5.85	3.335	57.0
February, . . .	3.51	2.463	70.3	5.23	5.616	107.3	3.14	1.574	50.1
March, ...	7.73	6.498	84.0	6.48	7.944	122.7	4.06	3.488	85.9
April, ...	2.64	3.236	122.3	3.91	4.138	106.0	0.83	1.504	181.1
May, ...	5.21	2.437	46.8	2.01	1.039	51.7	5.58	2.245	40.2
June, ...	2.03	0.980	48.3	3.77	0.714	18.9	2.76	0.739	26.8
July, ...	2.46	0.191	7.8	3.39	0.266	7.8	4.23	0.382	9.0
August, ...	3.87	0.235	6.1	4.73	0.290	6.1	4.44	0.500	11.3
September, . . .	6.00	0.790	13.2	2.38	0.350	14.7	2.84	0.396	13.9
October, ...	10.51	4.053	38.6	3.83	0.375	9.8	1.17	0.224	19.2
November, . . .	1.20	2.097	174.7	3.09	0.526	17.0	5.80	1.204	20.7
December, . . .	5.31	1.776	33.5	3.68	0.971	26.3	1.13	0.865	76.9
Totals and averages,	53.00	26.998	50.9	49.52	27.612	55.8	41.83	16.456	39.3

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1893.			1894.			1895.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	2.92	0.773	26.4	4.09	1.236	30.2	4.06	1.844	45.4
February,	8.20	2.485	30.3	3.91	1.596	40.8	1.39	0.871	62.5
March,	3.67	5.789	157.7	1.43	3.992	278.2	2.98	4.299	144.2
April,	3.60	3.668	101.7	3.42	2.832	82.9	5.25	4.341	82.7
May,	6.61	5.143	77.8	4.24	1.498	35.4	2.02	1.134	56.1
June,	2.38	0.759	31.9	1.15	0.723	62.6	2.77	0.301	10.8
July,	2.57	0.282	11.0	3.26	0.287	8.8	5.04	0.411	8.2
August,	5.41	0.322	5.9	2.03	0.373	18.4	4.15	0.409	9.9
September,	1.74	0.187	10.8	2.63	0.258	9.8	2.30	0.153	6.7
October,	4.07	0.395	9.7	5.34	0.668	12.5	10.68	2.460	23.0
November,	2.20	0.550	25.1	3.43	1.442	42.1	6.63	4.794	72.4
December,	4.86	1.421	29.2	4.81	1.277	26.5	3.35	3.179	94.9
Totals and averages,	48.23	21.774	45.2	39.74	16.182	40.7	50.62	24.196	47.8

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1896.			1897.			1898.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	2.39	1.933	80.9	4.00	1.507	37.6	6.83	2.922	42.8
February,	7.18	4.466	62.2	2.91	1.718	59.0	4.49	4.869	106.5
March,	5.24	6.841	130.7	3.66	4.575	125.0	2.40	4.645	193.5
April,	1.57	2.579	164.3	2.82	2.615	92.7	4.66	3.158	67.8
May,	2.57	0.641	24.9	4.37	1.632	37.3	3.22	2.222	68.9
June,	3.22	0.689	21.4	4.46	1.661	37.3	2.48	0.915	36.9
July,	2.51	0.170	6.8	5.44	1.174	21.6	4.09	0.411	10.1
August,	2.40	0.102	4.3	3.51	1.053	30.0	8.17	1.974	24.2
September,	7.72	0.669	8.7	2.94	0.315	10.7	2.62	0.637	24.4
October,	3.76	1.055	28.0	0.47	0.168	35.7	6.71	2.069	30.8
November,	3.02	1.137	37.7	6.40	1.570	24.5	6.93	3.429	49.5
December,	2.12	1.171	55.1	5.21	2.827	54.3	3.28	3.208	97.7
Totals and averages,	43.70	21.453	49.1	46.19	20.815	45.1	55.88	30.459	54.5

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1899. Rainfall.	1899. Rainfall collected.	1899. Per Cent. collected.	1900. Rainfall.	1900. Rainfall collected.	1900. Per Cent. collected.	1901. Rainfall.	1901. Rainfall collected.	1901. Per Cent. collected.
January,	4.18	4.082	97.7	4.96	1.417	28.6	1.82	0.779	42.7
February,	4.91	2.225	45.3	9.14	6.123	67.0	1.52	0.483	31.7
March,	7.01	7.501	107.0	6.35	6.518	102.6	6.57	4.912	74.8
April,	1.90	4.351	229.0	2.58	2.330	90.2	8.60	7.257	84.4
May,	1.45	0.911	62.8	4.32	2.341	54.2	7.23	5.269	72.9
June,	2.51	0.114	4.6	2.99	0.545	18.3	1.38	1.299	94.1
July,	3.22	0.035	1.1	2.42	—0.032	—1.3	5.71	0.545	9.6
August,	1.43	—0.063	—4.4	2.26	—0.060	—2.7	4.57	0.756	16.5
September,	3.95	0.162	4.1	3.36	0.112	3.3	3.30	0.527	15.9
October,	2.69	0.206	7.7	3.83	0.331	8.6	2.82	0.734	26.0
November,	2.18	0.525	24.1	5.70	1.144	20.1	2.90	0.819	28.3
December,	1.78	0.392	22.0	2.74	1.955	71.4	9.69	4.808	49.6
Totals and averages,	37.21	20.441	54.9	50.65	22.724	44.9	56.11	28.188	50.2

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1902. Rainfall.	1902. Rainfall collected.	1902. Per Cent. collected.	1903. Rainfall.	1903. Rainfall collected.	1903. Per Cent. collected.	1904. Rainfall.	1904. Rainfall collected.	1904. Per Cent. collected.
January,	2.52	3.145	125.1	3.80	3.096	81.4	4.87	0.851	17.5
February,	6.18	2.697	43.6	3.95	3.672	93.0	3.00	1.472	49.1
March,	5.34	7.491	140.3	6.63	6.161	92.9	2.72	5.349	196.8
April,	4.13	3.254	78.8	2.99	3.903	130.5	8.87	5.685	64.1
May,	1.86	1.325	71.3	0.93	0.625	67.4	2.65	3.112	117.7
June,	2.89	0.523	18.1	9.25	3.431	37.1	2.80	0.723	25.8
July,	2.94	0.117	4.0	2.77	0.794	28.7	1.96	0.111	5.7
August,	3.40	0.240	7.1	3.67	0.547	14.9	3.86	0.308	7.8
September,	4.54	0.308	6.8	1.75	0.225	12.8	5.80	0.685	11.8
October,	4.44	0.902	20.3	4.72	0.877	18.6	1.64	0.348	21.2
November,	1.45	0.767	52.7	1.56	0.626	40.2	1.73	0.499	28.8
December,	6.38	3.173	49.8	3.14	1.038	33.1	2.92	0.481	16.5
Totals and averages,	46.07	23.942	52.0	45.16	24.995	55.3	42.82	19.619	45.8

Rainfall, in Inches, received and collected, etc. — Continued.

Month.	1905. Rainfall.	1905. Rainfall collected.	1905. Per Cent. collected.	1906. Rainfall.	1906. Rainfall collected.	1906. Per Cent. collected.	1907. Rainfall.	1907. Rainfall collected.	1907. Per Cent. collected.
January,	5.26	2.516	47.8	2.47	2.012	81.5	3.28	2.411	73.4
February,	2.20	0.531	24.2	2.92	1.676	57.4	2.17	1.005	46.2
March,	3.15	4.456	141.6	6.32	4.297	68.0	1.91	2.958	154.6
April,	2.72	2.837	140.2	2.88	3.364	116.6	3.41	2.774	81.5
May,	1.31	0.530	40.3	5.66	1.890	33.4	3.63	1.584	43.6
June,	5.00	0.806	16.1	3.91	1.220	31.2	3.58	1.314	37.2
July,	5.47	0.316	5.8	3.42	0.709	20.7	1.86	0.015	0.8
August,	2.70	0.204	7.6	3.02	0.321	10.6	1.07	—0.186	—17.4
September,	6.88	2.152	31.3	3.30	0.034	1.0	8.76	0.934	10.7
October,	1.54	0.282	18.3	3.40	0.538	15.8	4.17	1.321	31.7
November,	2.07	0.481	23.3	2.69	0.834	31.1	6.12	3.450	56.4
December,	4.01	1.583	39.5	4.49	1.175	26.2	4.47	3.624	81.1
Totals and averages,	42.31	16.694	39.5	44.48	18.070	40.6	44.38	21.204	47.8

Rainfall, in Inches, received and collected, etc. — Concluded.

Month.	1908. Rainfall.	1908. Rainfall collected.	1908. Per Cent. collected.	Mean for Thirty-four Years, 1875–1908. Rainfall.	Mean for Thirty-four Years, 1875–1908. Rainfall collected.	Mean for Thirty-four Years, 1875–1908. Per Cent. collected.
January,	3.60	3.434	95.4	4.14	2.220	53.6
February,	4.56	2.564	56.3	4.18	2.837	67.9
March,	3.82	4.026	105.5	4.50	5.163	114.7
April,	1.88	1.929	102.6	3.50	3.543	101.1
May,	5.51	1.865	33.9	3.42	1.969	57.5
June,	0.86	0.335	38.9	3.11	0.903	29.0
July,	3.71	—0.025	—0.7	3.66	0.334	9.1
August,	4.57	0.181	4.0	3.91	0.473	12.1
September,	0.97	—0.141	—14.5	3.51	0.450	12.8
October,	2.55	0.083	3.3	4.07	0.862	21.2
November,	0.98	0.122	12.5	3.84	1.467	38.2
December,	3.14	0.243	7.7	3.84	1.898	49.4
Totals and averages,	36.15	14.616	40.4	45.70	22.120	48.4

The following table gives the records of the yield of the Sudbury River watershed for each year of the past thirty-four years, the flow from the watershed being expressed in gallons per day per square mile of watershed, in order to render the table more convenient for use in estimating the probable yield of watersheds used as sources of water supply: —

Yield of the Sudbury River Watershed in Gallons per Day per Square Mile.[1]

MONTH.	1875.	1876.	1877.	1878.	1879.	1880.	1881.
January,	103,000	643,000	658,000	1,810,000	700,000	1,121,000	415,000
February,	1,496,000	1,368,000	949,000	2,465,000	1,711,000	1,787,000	1,546,000
March,	1,604,000	4,435,000	4,813,000	3,507,000	2,330,000	1,374,000	4,004,000
April,	3,049,000	3,292,000	2,394,000	1,626,000	3,116,000	1,168,000	1,546,000
May,	1,188,000	1,139,000	1,391,000	1,394,000	1,114,000	514,000	965,000
June,	870,000	222,000	597,000	506,000	413,000	176,000	1,333,000
July,	321,000	183,000	202,000	128,000	158,000	177,000	276,000
August,	396,000	405,000	121,000	475,000	395,000	119,000	148,000
September,	207,000	184,000	60,000	160,000	141,000	80,000	197,000
October,	646,000	234,000	632,000	516,000	71,000	101,000	186,000
November,	1,302,000	1,088,000	1,418,000	1,693,000	206,000	205,000	395,000
December,	584,000	454,000	1,289,000	3,177,000	462,000	175,000	775,000
Average for whole year,	972,000	1,135,000	1,214,000	1,452,000	894,000	578,000	979,000
Average for driest six months,	574,000	384,000	502,000	532,000	230,000	143,000	330,000

MONTH.	1882.	1883.	1884.	1885.	1886.	1887.	1888.
January,	1,241,000	335,000	995,000	1,235,000	1,461,000	2,589,000	1,053,000
February,	2,403,000	1,033,000	2,842,000	1,354,000	4,800,000	2,829,000	1,951,000
March,	2,839,000	1,611,000	3,785,000	1,572,000	2,059,000	2,868,000	3,237,000
April,	867,000	1,350,000	2,853,000	1,815,000	1,947,000	2,620,000	2,645,000
May,	1,292,000	938,000	1,030,000	1,336,000	720,000	1,009,000	1,632,000
June,	529,000	300,000	417,000	426,000	203,000	414,000	422,000
July,	86,000	115,000	224,000	62,000	115,000	114,000	117,000
August,	55,000	78,000	257,000	240,000	94,000	214,000	380,000
September,	306,000	91,000	44,000	121,000	118,000	111,000	1,135,000
October,	299,000	186,000	83,000	336,000	146,000	190,000	1,999,000
November,	210,000	205,000	175,000	1,178,000	673,000	368,000	2,758,000
December,	314,000	193,000	925,000	1,174,000	1,020,000	643,000	3,043,000
Average for whole year,	862,000	533,000	1,129,000	901,000	1,087,000	1,154,000	1,697,000
Average for driest six months,	211,000	145,000	200,000	391,000	223,000	234,000	953,000

[1] The area of the Sudbury River watershed used in making up these records included water surfaces amounting to about 2 per cent. of the whole area, from 1875 to 1878 inclusive, subsequently increasing, by the construction of storage reservoirs, to about 3 per cent. in 1879, to 3.5 per cent. in 1885, to 4 per cent. in 1894 and to 6.5 per cent. in 1898. The watershed also contains extensive areas of swampy land, which, though covered with water at times, are not included in the above percentages of water surfaces.

Yield of the Sudbury River Watershed in Gallons per Day per Square Mile — Continued.

Month.	1889.	1890.	1891.	1892.	1893.	1894.	1895.
January,	2,782,000	1,254,000	3,018,000	1,870,000	433,000	698,000	1,034,000
February,	1,195,000	1,529,000	3,486,000	943,000	1,542,000	991,000	541,000
March,	1,389,000	3,643,000	4,453,000	1,955,000	3,245,000	2,238,000	2,410,000
April,	1,410,000	1,875,000	2,397,000	871,000	2,125,000	1,640,000	2,515,000
May,	880,000	1,366,000	582,000	1,259,000	2,883,000	840,000	636,000
June,	653,000	568,000	414,000	428,000	440,000	419,000	174,000
July,	683,000	108,000	149,000	214,000	158,000	161,000	231,000
August,	1,432,000	132,000	163,000	280,000	181,000	209,000	229,000
September,	824,000	458,000	203,000	229,000	108,000	150,000	89,000
October,	1,230,000	2,272,000	210,000	126,000	221,000	374,000	1,379,000
November,	1,941,000	1,215,000	305,000	697,000	319,000	836,000	2,777,000
December,	2,241,000	997,000	544,000	485,000	797,000	716,000	1,782,000
Average for whole year,	1,383,000	1,285,000	1,315,000	781,000	1,037,000	770,000	1,152,000
Average for driest six months,	944,000	747,000	239,000	327,000	237,000	356,000	460,000

Month.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
January,	1,064,000	845,000	1,638,000	2,288,000	794,000	437,000	1,763,000
February,	2,676,000	1,067,000	3,022,000	1,381,000	3,800,000	800,000	1,674,000
March,	3,835,000	2,565,000	2,604,000	4,205,000	3,654,000	2,755,000	4,199,000
April,	1,494,000	1,515,000	1,829,000	2,521,000	1,350,000	4,204,000	1,885,000
May,	360,000	915,000	1,246,000	511,000	1,312,000	2,954,000	743,000
June,	399,000	962,000	530,000	66,000	316,000	753,000	303,000
July,	95,000	658,000	231,000	19,000	—18,000	306,000	66,000
August,	57,000	591,000	1,107,000	—35,000	—34,000	424,000	135,000
September,	388,000	182,000	369,000	94,000	65,000	305,000	178,000
October,	592,000	94,000	1,160,000	115,000	186,000	412,000	506,000
November,	659,000	909,000	1,986,000	304,000	663,000	474,000	444,000
December,	657,000	1,584.000	1,799,000	220,000	1,096,000	2,695,000	1,779,000
Average for whole year,	1,019,000	991,000	1,450,000	973,000	1,082,000	1,342,000	1,140,000
Average for driest six months,	314,000	564,000	777,000	93,000	194,000	445,000	271,000

Yield of the Sudbury River Watershed in Gallons per Day per Square Mile— Concluded.

MONTH.	1903.	1904.	1905.	1906.	1907.	1908.	Mean for 34 Years, 1875-1908.
January,	1,786,000	477,000	1,410,000	1,128,000	1,851,000	1,925,000	1,245,000
February,	2,279,000	882,000	880,000	1,041,000	624,000	1,586,000	1,746,000
March,	3,454,000	2,999,000	2,497,000	2,409,000	1,658,000	2,257,000	2,894,000
April,	2,261,000	3,294,000	1,648,000	1,949,000	1,607,000	1,117,000	2,053,000
May,	851,000	1,745,000	297,000	1,059,000	888,000	1,046,000	1,104,000
June,	1,987,000	419,000	467,000	707,000	761,000	194,000	523,000
July,	445,000	62,000	177,000	398,000	9,000	—14,000	187,000
August,	807,000	170,000	114,000	180,000	—104,000	102,000	265,000
September,	180,000	397,000	1,246,000	19,000	541,000	—82,000	261,000
October,	492,000	191,000	158,000	301,000	741,000	47,000	483,000
November,	363,000	289,000	279,000	483,000	1,998,000	71,000	850,000
December,	582,000	269,000	887,000	659,000	2,082,000	136,000	1,064,000
Average for whole year,	1,190,000	931,000	795,000	860,000	1,010,000	694,000	1,058,000
Average for driest six months,	388,000	228,000	403,000	341,000	471,000	44,000	426,000

Nashua River.

The flow of the south branch of the Nashua River above Clinton during the year 1908 was 71 per cent. of the normal, making the year the driest since the records were begun, in 1897. The flow was in excess of the normal during the months of January, February and May, and below the normal during the remaining nine months of the year. The greatest excess occurred in January, and the greatest deficiencies in December and April. In order to show the relation between the flow of the Nashua River during each month of the year 1908 and the normal flow of that stream, as deduced from observations during twelve years, from 1897 to 1908, inclusive, the following table has been prepared. The area of the watershed of the Nashua River above the point of measurement was 119 square miles from 1897 to 1907, inclusive, and 118.19 square miles in 1908.

Table showing the Average Monthly Flow of the South Branch of the Nashua River for the Year 1908 in Cubic Feet per Second per Square Mile of Drainage Area, and in Million Gallons per Day per Square Mile of Drainage Area; also, Departure from the Normal Flow.

Month.	Normal Flow.		Actual Flow for 1908.		Excess or Deficiency.	
	Cubic Feet per Second per Square Mile.	Million Gallons per Day per Square Mile.	Cubic Feet per Second per Square Mile.	Million Gallons per Day per Square Mile.	Cubic Feet per Second per Square Mile.	Million Gallons per Day per Square Mile.
January,	1.929	1.247	2.689	1.738	+0.760	+0.491
February,	2.119	1.369	2.685	1.736	+0.566	+0.367
March,	4.415	2.854	3.391	2.192	−1.024	−0.662
April,	3.535	2.284	1.964	1.269	−1.571	−1.015
May,	1.932	1.248	2.188	1.415	+0.256	+0.167
June,	1.333	0.861	0.624	0.403	−0.709	−0.458
July,	0.759	0.490	0.341	0.220	−0.418	−0.270
August,	0.739	0.478	0.685	0.443	−0.054	−0.035
September,	0.679	0.439	0.136	0.088	−0.543	−0.351
October,	0.948	0.613	0.245	0.158	−0.703	−0.455
November,	1.385	0.895	0.194	0.125	−1.191	−0.770
December,	2.179	1.408	0.599	0.387	−1.580	−1.021
Average for whole year,	1.828	1.182	1.311	0.847	−0.517	−0.335

The following table gives the rainfall upon the Nashua River watershed and the total yield of the watershed, expressed in inches in depth on the watershed (inches of rainfall collected), for each of the twelve years from 1897 to 1908, inclusive, together with the average for that period: —

Rainfall, in Inches, received and collected on Nashua River Watershed.

Month.	1897.			1898.			1899.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	3.46	1.420	41.0	6.65	2.787	41.9	2.93	3.731	127.3
February,	2.86	1.500	52.4	3.30	2.635	79.8	5.12	1.757	34.3
March,	4.01	4.922	122.7	2.27	5.509	242.7	6.75	4.952	73.4
April,	2.32	2.818	121.5	4.43	3.500	79.0	1.94	5.829	300.5
May,	5.06	2.075	41.0	3.38	2.480	73.4	1.33	1.538	115.6
June,	5.11	2.039	39.9	3.11	1.429	46.0	5.51	0.969	17.6
July,	8.65	2.572	29.7	3.01	0.593	19.7	3.82	0.631	16.5
August,	3.47	1.599	46.1	10.61	2.363	22.3	3.20	0.421	13.2
September,	1.93	0.656	34.0	3.15	1.166	37.0	4.11	0.431	10.5
October,	0.94	0.434	46.2	7.21	2.691	37.3	2.72	0.437	16.1
November,	7.62	2.214	29.1	6.81	3.746	55.0	1.94	0.742	38.2
December,	6.41	4.059	63.3	3.99	3.676	92.1	2.03	0.640	31.5
Totals and averages,	51.84	26.308	50.7	57.92	32.575	56.2	41.40	22.078	53.3

Rainfall, in Inches, collected on Nashua River Watershed — Continued.

Month.	1900.			1901.			1902.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	4.56	1.420	31.1	1.75	0.926	52.9	2.72	2.990	109.9
February,	8.69	6.532	75.2	1.13	0.574	50.8	4.91	2.258	46.0
March,	6.19	6.639	107.3	5.82	4.849	83.3	5.27	7.120	135.1
April,	2.76	2.727	98.8	9.64	8.605	89.3	4.36	3.728	85.5
May,	4.34	2.467	56.8	7.02	4.867	69.3	2.24	1.839	82.1
June,	3.59	0.998	27.8	1.51	1.701	112.6	2.51	0.708	28.2
July,	3.20	0.388	12.1	5.66	0.851	15.0	3.87	0.521	13.5
August,	3.18	0.351	11.0	4.58	0.913	19.9	3.95	0.529	13.4
September,	3.46	0.220	6.4	3.10	0.552	17.8	4.26	0.416	9.8
October,	2.90	0.504	17.4	3.70	1.154	31.2	6.36	1.696	26.7
November,	6.44	1.510	23.4	2.43	0.892	36.7	0.93	1.095	117.7
December,	3.15	2.800	88.9	9.36	5.766	61.6	7.20	3.295	45.8
Totals and averages,	52.46	26.556	50.6	55.70	31.650	56.8	48.58	26.195	53.9

Month.	1903.			1904.			1905.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	2.85	2.256	79.2	4.02	1.176	29.3	6.10	2.258	37.0
February,	4.42	3.436	77.7	2.66	1.547	58.2	1.72	0.729	42.4
March,	6.58	6.107	92.8	3.40	5.361	157.7	3.95	5.358	135.7
April,	3.10	3.864	124.6	7.45	5.149	69.1	2.60	2.792	107.4
May,	1.24	1.015	81.9	2.99	2.671	89.3	0.83	0.794	95.7
June,	10.37	3.678	35.5	3.44	1.315	38.2	4.88	0.935	19.2
July,	3.43	1.114	32.5	3.84	0.886	23.1	5.39	0.651	12.1
August,	3.88	0.846	21.8	3.68	0.633	17.2	3.09	0.573	18.5
September,	2.93	0.647	22.1	5.30	0.853	16.1	6.90	2.119	30.7
October,	4.43	1.228	27.7	1.78	0.620	34.8	1.81	0.654	36.1
November,	2.36	1.095	46.4	1.62	0.591	36.5	2.52	0.763	30.3
December,	3.99	1.702	42.7	2.88	0.784	27.2	3.79	1.816	48.0
Totals and averages,	49.58	26.968	54.4	43.06	21.586	50.1	43.58	19.442	44.6

Rainfall, in Inches, collected on Nashua River Watershed — Concluded.

Month.	1906.			1907.			1908.		
	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	2.59	2.018	77.9	2.84	2.601	91.6	3.40	3.101	91.2
February,	2.74	1.654	60.4	2.32	1.115	48.0	4.82	2.896	60.0
March,	5.17	3.317	64.2	1.82	3.028	166.3	2.77	3.910	141.2
April,	3.12	3.640	116.7	2.65	2.479	93.5	2.62	2.191	83.5
May,	6.58	2.734	41.5	2.96	1.723	58.2	5.34	2.524	47.3
June,	5.95	2.043	34.3	3.54	1.334	37.7	1.29	0.696	54.0
July,	5.52	1.299	23.5	3.03	0.597	19.7	3.85	0.398	10.2
August,	4.34	1.055	24.3	1.26	0.155	12.3	6.49	0.790	12.2
September,	2.61	0.478	18.3	9.50	1.399	14.7	1.04	0.151	14.5
October,	3.95	0.945	24.0	5.68	2.465	43.4	2.12	0.282	13.3
November,	2.25	1.294	57.5	5.74	4.384	76.4	1.05	0.216	20.6
December,	4.26	1.417	33.3	4.40	3.499	79.5	3.03	0.691	22.8
Totals and averages,	49.08	21.894	44.6	45.74	24.778	54.2	37.82	17.841	47.3

Month.	Mean for 12 Years, 1897-1908.		
	Rainfall.	Rainfall collected.	Per Cent. collected.
January,	3.66	2.224	60.8
February,	3.72	2.219	59.6
March,	4.50	5.109	113.1
April,	3.92	3.944	100.7
May,	3.61	2.227	61.7
June,	4.23	1.487	35.1
July,	4.44	0.875	19.7
August,	4.31	0.852	19.8
September,	4.02	0.757	18.8
October,	3.63	1.093	30.1
November,	3.48	1.545	44.5
December,	4.54	2.512	55.3
Totals and averages,	48.06	24.825	51.7

The following table gives the records of the yield of this watershed for each year of the past twelve years, the flow being expressed in gallons per day per square mile of watershed: —

Yield of the Nashua River Watershed in Gallons per Day per Square Mile.[1]

Month.	1897.	1898.	1899.	1900.	1901.	1902.
January,	796,000	1,563,000	2,092,000	796,000	519,000	1,676,000
February,	931,000	1,635,000	1,090,000	4,054,000	356,000	1,401,000
March,	2,760,000	3,088,000	2,776,000	3,722,000	2,718,000	3,992,000
April,	1,632,000	2,027,000	3,376,000	1,580,000	4,986,000	2,158,000
May,	1,163,000	1,390,000	862,000	1,382,000	2,729,000	1,081,000
June,	1,181,000	828,000	561,000	578,000	985,000	410,000
July,	1,442,000	333,000	354,000	217,000	477,000	292,000
August,	896,000	1,325,000	236,000	197,000	512,000	297,000
September,	380,000	676,000	250,000	127,000	320,000	241,000
October,	243,000	1,509,000	245,000	282,000	647,000	950,000
November,	1,283,000	2,170,000	430,000	875,000	517,000	635,000
December,	2,275,000	2,061,000	359,000	1,570,000	3,234,000	1,848,000
Average for whole year,	1,253,000	1,551,000	1,051,000	1,264,000	1,507,000	1,248,000
Average for driest six months,	886,000	1,013,000	312,000	877,000	576,000	471,000

Month.	1903.	1904.	1905.	1906.	1907.	1908.	Mean for 12 Years 1897–1908.
January,	1,265,000	659,000	1,266,000	1,132,000	1,458,000	1,738,000	1,245,000
February,	2,133,000	927,000	452,000	1,027,000	692,000	1,736,000	1,746,000
March,	3,423,000	3,008,000	3,004,000	1,860,000	1,697,000	2,192,000	2,894,000
April,	2,238,000	2,984,000	1,617,000	2,109,000	1,436,000	1,268,000	2,053,000
May,	569,000	1,498,000	445,000	1,533,000	965,000	1,415,000	1,104,000
June,	2,131,000	762,000	542,000	1,184,000	773,000	403,000	523,000
July,	624,000	497,000	365,000	728,000	335,000	220,000	187,000
August,	474,000	355,000	321,000	591,000	87,000	443,000	265,000
September,	375,000	494,000	1,228,000	277,000	810,000	88,000	261,000
October,	689,000	347,000	367,000	530,000	1,382,000	158,000	483,000
November,	634,000	343,000	442,000	749,000	2,540,000	125,000	850,000
December,	954,000	440,000	1,018,000	794,000	1,961,000	387,000	1,064,000
Average for whole year,	1,285,000	1,025,000	926,000	1,043,000	1,180,000	847,000	1,053,000
Average for driest six months,	626,000	413,000	541,000	613,000	725,000	238,000	628,000

[1] The area of the watershed used in making up these records included water surfaces amounting to 2.2 per cent. of the whole area from 1897 to 1902, inclusive, to 2.4 per cent. in 1903, to 3.6 per cent. in 1904, to 4.1 per cent. in 1905, to 5.1 per cent. in 1906, to 6 per cent. in 1907 and to 7 per cent. in 1908.

Merrimack River.

The flow of the Merrimack River at Lawrence has been measured for many years by the Essex Company, from whom a continuous record of the measurements made from June 1, 1887, to Jan. 1, 1909, has been obtained.

The total area of the watershed tributary at that place is 4,664 square miles, which includes at the present time 118 square miles on the south branch of the Nashua River, 75 square miles on the Sudbury River and 19 square miles tributary to Lake Cochituate, or a combined area

of 212 square miles from which water is drawn for the supply of the metropolitan water district. The flow as measured at Lawrence includes the water wasted from these three watersheds, which, in the wet months of the year, is very considerable, but which becomes very small in the dry months. Records of the quantity of water wasted have been kept by the Boston water board and by the Metropolitan Water Board, and these quantities have been deducted from the flow as measured at Lawrence. The area of the three watersheds has also been deducted from the watershed area at Lawrence, so that the net area was 4,570 square miles up to March 1, 1898, at which time the Nashua River was diverted, 4,451 square miles from March 1, 1898, to Jan. 1, 1908, and 4,452 square miles in 1908.

The flow of the Merrimack River during the year 1908 was about 75 per cent. of the normal, making the year the driest that has occurred during the past twenty-one years for which records are available. The flow was in excess of the normal in the months of January, February and May, but less than the normal in the remaining nine months of the year. The greatest excess occurred in January and the greatest deficiency in April. In order to show the relation between the flow of this stream during each month of the year 1908 and the normal flow of the stream, as deduced from observations during twenty-one years, from 1888 to 1908, inclusive, the following table has been prepared: —

Table showing the Average Monthly Flow of the Merrimack River for the Year 1908, in Cubic Feet per Second per Square Mile of Drainage Area, and the Departure from the Normal Flow.

MONTH.	Normal Flow. Cubic Feet per Second per Square Mile.	Actual Flow in 1908. Cubic Feet per Second per Square Mile.	Excess or Deficiency. Cubic Feet per Second per Square Mile.
January,	1.549	1.946	+0.397
February,	1.484	1.648	+0.164
March,	3.115	2.499	—0.616
April,	3.879	2.652	—1.227
May,	2.412	2.570	+0.158
June,	1.345	0.932	—0.413
July,	0.770	0.522	—0.248
August,	0.689	0.668	—0.021
September,	0.756	0.379	—0.377
October,	1.035	0.330	—0.705
November,	1.341	0.354	—0.987
December,	1.462	0.420	—1.042
Average for the year,	1.653	1.243	—0.410

The following table gives the record of the net flow of this stream for each year of the past twenty-one years, the flow being expressed in cubic feet per second per square mile of watershed: —

Flow of the Merrimack River at Lawrence in Cubic Feet per Second per Square Mile of Drainage Area.

Month.	1888.	1889.	1890.	1891.	1892.	1893.
January,	2.133	2.905	1.931	3.510	2.492	0.645
February,	2.759	1.548	2.233	3.168	1.247	1.061
March,	3.000	2.651	3.697	5.720	1.773	2.371
April,	6.010	2.675	4.122	5.165	1.966	3.841
May,	5.137	1.653	3.423	1.734	2.525	4.910
June,	1.411	1.336	1.877	1.077	1.435	1.132
July,	0.533	0.867	0.727	0.673	1.134	0.546
August,	0.577	1.243	0.770	0.541	1.123	0.564
September,	1.694	0.795	2.017	0.572	0.971	0.599
October,	2.945	1.417	2.973	0.459	0.487	0.398
November,	3.218	2.208	2.103	0.551	1.638	0.851
December,	3.562	3.153	1.573	0.959	1.006	1.074
Average for whole year,	2.748	1.871	2.287	2.011	1.488	1.543
Average for driest six months,	1.730	1.219	1.745	0.626	1.060	0.755

Month.	1894.	1895.	1896.	1897.	1898.	1899.
January,	0.869	0.626	1.406	0.745	1.613	1.657
February,	1.121	0.506	1.941	1.000	1.638	1.083
March,	3.115	1.258	4.509	2.294	4.043	2.479
April,	2.401	4.290	3.967	3.339	3.317	5.758
May,	1.541	1.360	0.971	2.209	2.400	2.121
June,	1.387	0.664	0.769	2.769	1.417	0.667
July,	0.496	0.565	0.446	2.359	0.585	0.556
August,	0.370	0.477	0.441	1.105	0.776	0.468
September,	0.400	0.366	0.683	0.603	0.636	0.447
October,	0.493	0.363	1.134	0.482	1.371	0.401
November,	0.772	2,046	1.454	1.274	2.095	0.625
December,	0.661	2.025	0.949	2.262	1.871	0.580
Average for whole year,	1.136	1.254	1.556	1.745	1.820	1.396
Average for driest six months,	0.532	0.716	0.741	1.347	1.146	0.506

Flow of the Merrimack River at Lawrence in Cubic Feet per Second per Square Mile of Drainage Area — Concluded.

MONTH.	1900.	1901.	1902.	1903.	1904.
January,	0.748	0.758	2.268	1.684	0.584
February,	3.520	0.546	1.195	1.979	0.644
March,	3.441	2.064	6.012	6.032	2.719
April,	4.068	5.568	3.801	3.376	4.495
May,	2.185	3.335	2.256	0.979	3.844
June,	0.878	1.657	1.187	2.224	1.032
July,	0.407	0.646	0.971	1.032	0.624
August,	0.420	0.989	0.844	0.734	0.573
September,	0.338	0.588	0.774	0.580	0.653
October,	0.564	0.913	1.600	0.823	0.816
November,	1.304	0.670	1.285	0.665	0.604
December,	1.498	2.053	1.756	0.825	0.408
Average for whole year,	1.616	1.648	1.996	1.740	1.416
Average for driest six months,	0.652	0.911	1.110	0.768	0.613

MONTH.	1905.	1905.	1907.	1908.	Mean for 21 Years, 1888–1908.
January,	0.855	1.696	1.411	1.946	1.549
February,	0.503	1.183	0.667	1.648	1.484
March,	2.350	1.678	1.728	2.499	3.115
April,	3.616	3.591	2.924	2.652	3.879
May,	1.169	2.269	2.034	2.570	2.412
June,	0.961	2.262	1.190	0.932	1.345
July,	0.600	1.106	0.749	0.522	0.770
August,	0.606	0.741	0.431	0.668	0.689
September,	1.706	0.422	0.664	0.379	0.756
October,	0.727	0.549	1.433	0.330	1.035
November,	0.760	0.707	2.914	0.354	1.341
December,	1.274	0.567	2.177	0.420	1.462
Average for whole year,	1.258	1.398	1.527	1.248	1.653
Average for driest six months,	0.888	0.682	1.083	0.445	0.989

Sudbury, Nashua and Merrimack Rivers.

The following table shows the weekly fluctuation during 1908 in the flow of the three streams just described, namely, the Sudbury River at Framingham, the south branch of the Nashua River above Clinton and the Merrimack River at Lawrence. The flow of these streams, particularly that of the Sudbury and of the south branch of the Nashua River, serves to indicate the flow of other streams in eastern Massachusetts. The area of the Sudbury River watershed is 75.2 square miles and of the south branch of the Nashua River 118.19 square miles. The net watershed area of the Merrimack River is 4,452 square miles.

Table showing the Average Weekly Flow of the Sudbury, South Branch of the Nashua and Merrimack Rivers for the Year 1908 in Cubic Feet per Second per Square Mile of Drainage Area.

Week Ending Sunday.	Flow in Cubic Feet per Second per Square Mile.			Week Ending Sunday.	Flow in Cubic Feet per Second per Square Mile.		
	Sudbury River.	South Branch Nashua River.	Merrimack River.		Sudbury River.	South Branch Nashua River.	Merrimack River.
Jan. 5, . .	3.494	3.256	2.511	July 5, . .	—0.042	0.398	0.481
12, . .	4.125	4.338	2.135	12, . .	—0.363	0.055	0.505
19, . .	4.189	2.987	2.450	19, . .	—0.111	0.268	0.388
26, . .	1.304	1.742	1.328	26, . .	0.547	0.719	0.635
Feb. 2, . .	2.664	1.840	1.308	Aug. 2, . .	—0.210	0.141	0.544
9, . .	1.262	1.451	0.943	9, . .	0.673	1.516	0.898
16, . .	2.964	5.078	1.384	16, . .	0.016	0.871	0.799
23, . .	2.454	2.172	2.965	23, . .	—0.118	0.291	0.604
Mar. 1, . .	2.280	2.030	1.430	30, . .	0.066	0.378	0.539
8, . .	2.541	1.878	1.321	Sept. 6, . .	—0.143	0.071	0.459
15, . .	4.056	4.554	1.637	13, . .	—0.060	0.060	0.407
22, . .	4.291	3.962	3.058	20, . .	—0.339	—0.027	0.396
29, . .	3.090	3.424	3.462	27, . .	—0.089	0.142	0.277
April 5, . .	2.798	2.412	3.713	Oct. 4, . .	—0.032	0.368	0.327
12, . .	2.396	2.232	2.544	11, . .	—0.029	0.159	0.327
19, . .	1.652	1.917	2.359	18, . .	—0.226	0.095	0.335
26, . .	1.138	1.744	2.193	25, . .	0.367	0.126	0.331
May 3, . .	1.023	1.817	3.486	Nov. 1, . .	0.652	0.661	0.306
10, . .	0.601	3.330	3.422	8, . .	—0.033	—0.005	0.376
17, . .	1.414	1.906	3.070	15, . .	—0.523	0.237	0.358
24, . .	1.408	1.437	1.940	22, . .	0.907	0.219	0.361
31, . .	1.530	2.123	1.422	29, . .	0.105	0.327	0.329
June 7, . .	1.373	1.349	1.799	Dec. 6, . .	—0.706	0.169	0.443
14, . .	0.166	0.487	0.874	13, . .	0.857	1.172	0.435
21, . .	0.039	0.506	0.623	20, . .	0.143	0.616	0.456
28, . .	—0.068	0.232	0.497	27, . .	0.013	0.397	0.316

A Review of Twenty-one Years' Experiments

UPON THE

PURIFICATION OF SEWAGE

AT THE

LAWRENCE EXPERIMENT STATION.

By H. W. Clark and Stephen DeM. Gage.

A Review of Twenty-one Years' Experiments upon the Purification of Sewage at the Lawrence Experiment Station.

By H. W. Clark and Stephen DeM. Gage.

The year 1908 is the twenty-first of the operation of the Lawrence Experiment Station. The act of the Legislature under which the systematic work of the Massachusetts State Board of Health on the examination of water supplies, the purification of sewage and water, etc., was begun, was passed in 1886. The report of the Board for the year 1887 contained an account of the establishment of the experiment station and of the preliminary work done there. A chemical laboratory was installed in 1888 and a laboratory for bacteriological and microscopical work in 1890. These laboratories have been enlarged and improved from time to time, and in them about 50,000 chemical and 150,000 bacterial analyses have been made during the past twenty years, and new and more accurate chemical, biological and physical methods have been developed for the study of water, sewage, sands, soils, etc. Beginning with studies upon intermittent sand filtration of sewage and water, together with laboratory investigations upon nitrification, the causes of the reduction of bacteria by filtration, etc., the work of the station has grown constantly, and at the present time includes experimental investigations tending toward the development of scientific methods of sewage purification, of the purification of manufacturing wastes of many kinds, and other special investigations in sanitary science which will be referred to later.

It may be said fairly that the investigations at the Lawrence Experiment Station laid the foundations for the scientific treatment of sewage and have given the initiative for similar investigations in this and other countries. The work was planned by Hiram F. Mills, A.M., C.E., a member of the State Board of Health, and has been carried on under his general supervision. A full account of the early equipment of the station and of the work done there during the years 1888, 1889 and 1890, is to be found in a special report of the Board for 1890, prepared by Mr. Mills. This special report has been for many years the most

widely known work upon sewage purification. The work of subsequent years has been published in the annual reports, and detailed information should be sought in these documents.[1] It is hoped to give here, however, a clear idea of the main work carried on at the station during the past twenty-one years.

Résumé of Work in Different Years.

The report by Hiram F. Mills, A.M., C.E., mentioned above, covers thoroughly the investigations made during 1888, 1889 and 1890 upon the subject of sewage purification. During these three years, sewage had been filtered intermittently through gravel-stones, through filters made of various grades of gravel and through sand, even through a fine sand averaging but 0.004 inch in diameter, — a fine granular dust, — as well as through soils and peats. It was found that, with all the filters, from the coarsest to the finest, purification by nitrification took place best when the sewage applied was adapted to the working ability of the filter, and the surface not allowed to become clogged by organic matter, to the exclusion of air. It was shown, furthermore, that fine soils retained water so long that the quantity of sewage which could be applied was small, although such a filter might give an effluent free from bacteria. With thicker layers of these fine soils, moreover, it was found that nitrification did not take place, and that the organic matter in the effluent was nearly as great as in the sewage, although no bacteria probably passed through the filter. It was found that peat filters, though but 1 foot in depth, were practically impervious to liquid, and that intermittent filtration with such material was impracticable. Experiments with gravel-stones gave the best illustration of the essential character of intermittent filtration of sewage. Filters were constructed of stones, so large that even the coarser suspended particles of the sewage were not removed; yet "the slow movement of the sewage in thin films over the surface of the stones, with air in contact, caused a

[1] At the beginning of this work, Dr. Thomas M. Drown of the Massachusetts Institute of Technology was appointed chemist to the Board and given general supervision of the chemical work, both at Lawrence and Boston. When, in 1895, Dr. Drown became president of Lehigh University, he was made consulting chemist to the Board, and served in that capacity until his death in 1904. At the station Mr. Allen Hazen was in charge until March, 1893, when he was succeeded by Mr. George W. Fuller. Since August, 1895, a period of fourteen years, Mr. H. W. Clark, who had been connected with the Lawrence work almost from its start, and who also succeeded Dr. Drown as chemist to the Board, has been in charge at the station, and since 1896 of the Boston laboratories of the department of water supply and sewerage. Mr. Fred B. Forbes and Mr. W. R. Copeland have been prominent among the many assistants at the station during the first twenty-one years, and Mr. Forbes is still in the employ of the Board as chief assistant in the laboratories at the State House. Mr. Stephen DeM. Gage, biologist, and Mr. George O. Adams, chemist, are the chief assistants at the station at the present time, Mr. Gage having been connected with the work since 1896 and Mr. Adams since 1900. For short periods in the beginning, the bacterial work was in the charge of various biologists; but in November, 1888, Dr. Wm. T. Sedgwick was appointed biologist to the Board, and so remained until 1896.

removal for some months of 97 per cent. of the organic nitrogenous matter as well as 99 per cent. of bacteria." These filters were the forerunners of the sprinkling or trickling filters now so well known in sewage purification. It was found also, and stated in the special report for 1890, that "the mechanical separation of any part of a sewage by straining through sand is but an incident which, under some conditions, favorably modifies the results, but the essential conditions are very slow motion of very thin films of liquid over the surface of the particles that have spaces between them sufficient to allow air to be in contact with the films of liquid. . . . With these conditions it is essential that certain bacteria be present to aid in the process of nitrification." It appeared, furthermore, and was so stated in the same report, that the "filters gave an effluent some time before nitrification began which contained from 20 to 40 per cent. as much free and albuminoid ammonia as the sewage. During the cold months of the very cold winter in which the first filters were started there was an important step in purification going on. This was the conversion of albuminoid ammonia to free ammonia, or, to state the case more definitely, it was the burning up of a part of the organic matter by the combination of oxygen with some of the carbon, producing carbonic acid, and leaving the nitrogen and hydrogen that were contained with this carbon to form ammonia, thus reducing the amount of combined nitrogen which in our analyses appears as albuminoid ammonia. This is as complete a destruction of organic matter, as far as it goes, as if the free ammonia were again oxidized, forming nitric acid or nitrates, but this process seldom, if ever, carries the destruction of the organic impurities of the sewage to such an extent that the resulting liquid contains as little impurity as when nitrification takes place. We find further that this process of reducing the albuminoid ammonia is not so destructive to bacteria as the more complete process of nitrification. It is, however, a process of purification, and the conditions of intermittent filtration are those most favorable to this step in purification."

This special report for 1890 gave the results observed in all the sewage filters, 19 in number, that were operated up to the end of 1890. It gave also many data in regard to special investigations concerning the mechanical and physical characteristics of the materials employed in filtration; the storage of nitrogen; time of flow of sewage through filters 5 feet in depth, this being measured by the change in chlorine contents of the effluent; special studies upon nitrification and nitrifying organisms; articles upon the chemical and biological work at the station, chemical precipitation of sewage, etc.

The report for 1891 took up the subjects of the permanency of filters;

the mechanical composition of materials used in filters, together with the conclusions drawn from a study of the materials and the results of filtration, as showing the capacity of each material to purify sewage; the best method of applying sewage to different grades of sand, etc., together with further experiments on the bacterial efficiency of the filters at that time in operation. Early in this year a gravel filter was operated at a rate of 220,000 gallons per acre daily, the sewage being applied in sixty or seventy doses per day. Good nitrification results were obtained without artificial aeration of the filter; in fact, this was a true trickling filter as now known.

In 1892 and 1893 special studies were made of the care of sewage filters; stratification and the effect of horizontal layers; filtration of sewage containing dyestuffs; the rate of filtration through various materials; the causes of clogging of sewage filters, and the removal of this clogging matter from the sand. In these years, also, studies of rapid filtration aided by artificial aeration of the filters were begun. The report for 1892 contained, in addition, a very important article upon the physical properties of sands and gravels with especial reference to their use in filtration.

In 1894 a general review of the work upon sewage purification at the station up to and including that year was given. Special investigations were made at that time upon the composition of sewage and the changes which occurred in sewage as it ages. It was shown, for instance, that storage of fresh Lawrence sewage for twenty-four hours doubled the free ammonia and decreased the organic nitrogen present one-half. Other changes, such as an increase in the number of bacteria present, also took place. This work antedated the operation of septic tanks. At this time a series of sewage samples were collected at different periods of the day from various sewage-disposal areas and institutions in the State, and were examined to show the varying strengths of the sewage at different hours, and the amount of organic matter of different kinds in the sewage per person contributing to the flow.

In 1895 investigations were continued as to the best methods of treating sewage filters to insure permanency; on the best preliminary treatment of sewage to remove sludge before filtration and the different methods of aerating sewage filters. In this year, also, were made the first experiments upon the purification by filtration of industrial sewage as seen in tanneries, paper mills, wool-scouring works, etc. The stable character of the effluents from trickling filters operated at high rates and aerated a portion of the time by means of a current of air was first shown at this period. It was found that "the organic matter in the liquids, after rapid filtration combined with aeration, is of a different

the sewage when pumped at the station. These tables give the composition of the station sewage during the entire period under review, but regular collection of samples for analysis from the Lawrence Street sewer was not begun until 1894. The sewage of the station is, as stated, pumped from the sewer which serves the most densely populated section of the city, but during recent years some additions and extensions to the branch sewers have made this sewage, owing to the larger area served and the resulting increased ground-water leakage, somewhat less strong than during the period previous to 1901. The sewage used at the station is pumped from the sewer between the hours of 6 A.M. and 5 P.M., during that portion of the day when the strongest sewage is flowing, that is to say, when the sewage contains the greatest amount of organic matter per volume of liquid. This preponderance of strength at certain hours is clearly brought out by the following table of analyses of samples collected from the sewer during a day of twenty-four hours of normal weather and flow. The samples of sewage collected directly from the sewer for analysis each week have also always been collected during the day, and represent strong day sewage. The table shows that the sewage collected during certain hours of the working day contains from three to four times as much organic matter as sewage collected during certain hours of the night. A study of these tables, together with tables in the various annual reports which present not only analyses of samples from this sewer, but also from the main sewers of other cities and towns in the State, confirms the statement that the amount of solid and organic matter is fully twice as great in the day flow as in the night flow. A certain amount of the insoluble matters in the Lawrence Street sewage, especially sand, settles in the long pipe reaching from the sewer to the station, and this pipe requires flushing from time to time. The amount of solid matter which settles in this pipe, however, has but slight effect upon the average strength of the station sewage.

of bacteria necessary for sludge disposal,"[1] and the tank was so arranged that the sewage passed upward through this stone. As the result of other researches, it was shown that prolongation of anaerobic action might impede subsequent purification by filtration. There were made also this year special studies relating to the purification of the wastes from creameries, and to the action of iron and iron oxides on the purification of sewage by filtration.

In 1900 analyses and measurements of the gas produced by septic tanks were made and investigations concerning the efficiency of septic treatment of different classes of sewage; also experiments upon the sterilization of septic sewage to show whether or not the air that it was necessary to introduce into some classes of septic sewage, before efficient purification by filtration could be assured, was required because of the rapid use of the oxygen by bacteria or because of its absorption by organic matter and gases. Operation of the hydrolytic tank, together with various trickling filters, and the study of purification of manufacturing wastes were continued.

In 1901 a thorough investigation was made of the stability of the effluents and of the organic matter left in the effluents of contact and trickling filters, together with observations on the improvement of such effluents when mixed with river water. The rate and degree of clogging of contact filters and the methods necessary to remove this clogging material were studied also. In this year contact filters of roofing-slate and brick, with regular spaces between each pair of slates or bricks, were first put into operation. Two of these filters are described in the report for 1901, the slate filters being similar to those operated in more recent years in England by Dibdin.

In 1902 studies of contact and trickling filters, especially those of the latter, were continued, together with special investigations concerning nitrification and the removal of organic matter from the upper layers of sand filters.

In 1903 special efforts were made to learn the cause of the poorer winter nitrification in the older intermittent sand filters, in order to improve the work of these filters. Studies of septic tanks and of the operation of contact filters constructed of different materials and depths, with special regard to permanency of operation, were continued, together with allied studies upon the stability of their effluents. Studies were made also of the purification of sewage by trickling filters of different materials and different depths, and investigations in regard to the stability of the effluents of these filters and experiments upon sedimentation, secondary filtration, etc., of these effluents were undertaken. Numerous

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[1] Page 426, report for 1899.

experiments were made on the purification of dye liquors and the waste from gas works, together with studies on methods of analysis with special regard to the comparative value of albuminoid ammonia and Kjeldahl determinations of nitrogen; of incubation of effluents; and of the nitrification and denitrification caused by sand, effluents and species of bacteria from filters in which either nitrification or reducing actions were occurring.

The year 1904 was devoted largely to the improvement of the sand filters that had been in operation for sixteen years, and to studies of methods for the disposal of nitrogenous and other organic matters by these filters; special studies of nitrification; studies of the respective amounts of nitrogen and carbon oxidized, stored or liberated from experimental and municipal sand filters; studies of the determination of acidity or alkalinity as an index of the degree of purification of filter effluents; studies of the bacteriology and biochemistry of sewage purification. A new method for the determination of turbidity of the effluents of filters and of water was developed and first used during this year. Studies were made also of the time of passage of sewage through trickling filters constructed of different materials and of different depths, and of the rapidity of oxidation and purification of these filters.

In 1905 a continuation was made of the studies of the organic matters, nitrogen, fats, carbon, etc., in sludge and in sewage, and of the same substances stored in filters; studies of the relative amounts of nitrogen, carbon and fatty matters in sewage, sludge and the effluents of trickling and contact filters and appropriate methods for their analysis. Moreover, special studies were taken up again as to the refiltration of trickling filter effluents through sand filters.

In 1906 a complete résumé was given of the comparative value of sand, contact and trickling filters for the disposal of organic matter, and the comparative rates at which such filters can be operated; of the rate of filtration and amount of suspended matter in sewage applied to sand filters as related to volume of sand removed; of the coagulation and mechanical filtration of the effluents of trickling filters, together with more complete studies of methods for the application of sewage to trickling filters; of the comparative rates of filtration maintained by sand filters; of continued studies on the purification of industrial wastes.

In 1907 the most important special work was a continued study of methods for the distribution of sewage upon trickling filters and observations on the refiltration of trickling filter effluents through sand, coagulation and mechanical filters.

The number of filters at the station — sand, contact and trickling

filters — has increased steadily until, at the end of 1908, 250 filters for the purification of sewage have been in operation. Since 1895, moreover, much attention has been given to the purification of wastes from manufacturing industries, and, as a result, reasonable and efficient methods for the treatment of most of these wastes have been developed and published in the annual reports. Among the wastes studied have been those from tanneries, paper mills, carpet mills, paint mills, woolen mills, wool-scouring works, dye works, shoddy mills, creameries, yeast factories, glue works, gas works, etc.

Composition of Sewage used in the Lawrence Experiments.

The sewage used at the station is taken from the main sewer of the city at a point above that at which are discharged into the sewer the water and wastes from the large mills lining the banks of the Merrimack River. This sewage, which is strictly domestic in character, is pumped through an iron pipe 2½ inches in diameter and about 4,300 feet long, from a point in the sewer about 1,000 feet above its mouth, thence through the bed of the Merrimack River to the station. This sewer receives street-wash as well as domestic sewage, but the district in the city of Lawrence served by it is as thickly populated probably as any area of equal size in the State of Massachusetts. The time taken for the passage of sewage through the pipe to the experiment station is from two to three hours, and during this period bacterial action, together with the natural disintegration of the easily broken solid matter, causes the sewage to change quite materially in character. In the sewer, the mixture of organic matter and water is so recent that the sewage contains dissolved oxygen, and the limited amount of bacterial action which the sewage has undergone at this point is indicated by the small amount of free ammonia as compared with the large amount of albuminoid ammonia. The sewage at this point also contains nitrates and nitrites, and the oxygen consumed from permanganate is high, showing that the oxidation of carbonaceous matter to carbonic acid has not advanced greatly. The sewage on reaching the station has lost its dissolved oxygen, the oxygen consumed from permanganate is lower, the free ammonia is higher and the amount of organic matter in solution compared with that in suspension is greater, indicating that considerable organic matter has been already oxidized to ammonium carbonate. Sewage such as that flowing in the sewer is designated as "fresh" sewage. When it reaches the experiment station it is known as "stale" sewage.

Following tables, on pages 265 and 266, give the average analyses year by year of samples of sewage collected from the Lawrence Street sewer at a point where the sewage enters the pipe leading to the station and of

the sewage when pumped at the station. These tables give the composition of the station sewage during the entire period under review, but regular collection of samples for analysis from the Lawrence Street sewer was not begun until 1894. The sewage of the station is, as stated, pumped from the sewer which serves the most densely populated section of the city, but during recent years some additions and extensions to the branch sewers have made this sewage, owing to the larger area served and the resulting increased ground-water leakage, somewhat less strong than during the period previous to 1901. The sewage used at the station is pumped from the sewer between the hours of 6 A.M. and 5 P.M., during that portion of the day when the strongest sewage is flowing, that is to say, when the sewage contains the greatest amount of organic matter per volume of liquid. This preponderance of strength at certain hours is clearly brought out by the following table of analyses of samples collected from the sewer during a day of twenty-four hours of normal weather and flow. The samples of sewage collected directly from the sewer for analysis each week have also always been collected during the day, and represent strong day sewage. The table shows that the sewage collected during certain hours of the working day contains from three to four times as much organic matter as sewage collected during certain hours of the night. A study of these tables, together with tables in the various annual reports which present not only analyses of samples from this sewer, but also from the main sewers of other cities and towns in the State, confirms the statement that the amount of solid and organic matter is fully twice as great in the day flow as in the night flow. A certain amount of the insoluble matters in the Lawrence Street sewage, especially sand, settles in the long pipe reaching from the sewer to the station, and this pipe requires flushing from time to time. The amount of solid matter which settles in this pipe, however, has but slight effect upon the average strength of the station sewage.

Average Analyses of Lawrence Street Sewage collected during a Day of Twenty-four Hours of Normal Weather and Flow.[1]

[Parts per 100,000.]

1908.	Residue on Evaporation.						Ammonia.			Kjeldahl Nitrogen.		Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
	Unfiltered.			Filtered.				Albuminoid.						
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.	Free.	Total.	In Solution.	Total.	In Solution.			
Sept. 15: 3.30-5 P.M.,	96.3	47.7	48.6	73.0	28.4	44.6	2.80	0.78	.35	1.63	0.88	14.10	8.40	4,350,000
5.30-7 P.M.,	113.8	56.0	57.8	67.6	20.4	47.2	3.10	1.06	.42	2.54	1.10	14.50	12.00	3,770,000
7.30-9 P.M.,	107.5	49.4	58.1	73.9	23.0	50.9	4.50	0.84	.46	2.04	0.94	20.00	8.00	3,500,000
9.30-11 P.M.,	132.8	48.7	84.1	108.6	24.8	83.8	6.10	1.02	.50	2.00	1.35	40.50	8.80	2,875,000
11.30-1 A.M.,	66.2	30.7	35.5	48.8	16.3	32.5	4.30	0.66	.22	1.33	0.57	12.50	6.40	3,200,000
Sept. 16: 1.30-3 A.M.,	44.9	16.7	28.2	33.6	8.8	24.8	1.70	0.32	.19	0.71	0.51	9.30	6.33	1,170,000
3.30-5 A.M.,	52.2	20.2	32.0	31.5	6.9	24.6	1.70	0.36	.18	0.77	0.31	8.60	6.38	1,555,000
5.30-7 A.M.,	79.9	36.2	43.7	54.3	16.9	37.4	6.80	1.14	.69	2.28	1.71	14.40	7.38	2,950,000
7.30-9 A.M.,	147.7	63.4	84.3	96.5	23.6	72.9	6.90	1.66	.78	3.57	1.78	34.50	11.60	4,000,000
9.30-11 A.M.,	133.9	68.6	65.3	74.6	22.6	52.0	3.90	1.58	.60	3.04	1.08	20.70	8.99	4,220,000
11.30-1 P.M.,	124.6	61.3	63.3	71.6	16.6	55.0	3.40	1.04	.51	2.77	1.59	17.60	8.57	2,800,000
1.30-3 P.M.,	110.5	52.0	58.5	61.5	15.0	46.5	3.20	1.08	.65	2.83	1.54	14.40	7.19	2,115,000

[1] Each sample is the average of 4 samples collected at half-hour intervals.

CHARACTER OF SEWAGE.

The regular station sewage is stronger than the average sewage of the cities and towns of Massachusetts having filtration areas. This is shown by comparing the table of average analyses of station sewage with the table following, the figures upon which represent the *day flow* of sewage in various cities and towns, and are averages of samples forwarded to the laboratory of the Board for analysis. Contrary to many statements, moreover, the sewage used during the last fifteen or sixteen years in these experiments is as strong as average English sewage. This can be determined easily by comparing the analyses given in this report with those of average English sewage, as presented in the fifth report of the Royal Commission on Sewage Disposal. Such typical English communities as Accrington, Birmingham, Leeds, Manchester, Rochdale, Sheffield, York, Chorley and Heywood are represented in this report.

Average Analyses of Sewage of Various Cities and Towns in Massachusetts during 1908.

[Parts per 100,000.]

City or Town.	Total Residue.	Loss on Ignition.	Ammonia.			Chlorine.	Oxygen Consumed (Unfiltered).
			Free.	Albuminoid.			
		Total.		Total.	In Solution.		
Andover,	37.81	21.17	2.70	0.56	.22	4.08	3.78
Brockton,	133.62	82.46	7.07	2.04	.42	14.89	24.37
Clinton,	59.75	25.12	3.80	0.68	.33	5.25	5.71
Concord,	24.32	10.35	1.18	0.27	.14	3.07	1.79
Framingham,	45.93	18.16	3.64	0.62	.37	7.69	4.00
Gardner,[1]	44.64	24.59	6.28	0.97	.45	4.91	5.74
Gardner,[2]	117.98	72.54	5.69	1.55	.53	12.20	8.56
Hopedale,	61.88	32.52	5.02	0.88	.35	6.90	6.17
Leicester,	39.48	18.77	4.47	0.51	.22	5.33	4.30
Marlborough,	38.08	30.37	2.90	0.65	.23	4.72	3.61
Natick,	45.44	19.59	3.05	0.52	.21	6.38	4.16
Pittsfield,	32.73	13.11	1.87	0.26	.13	3.54	2.47
Spencer,	41.60	22.25	4.08	0.84	.33	5.29	4.82
Stockbridge,	25.33	11.92	0.99	0.24	.08	1.30	1.79
Westborough,	89.78	51.15	2.65	1.51	.94	6.44	31.58
Average,	55.28	30.27	3.69	0.81	.33	6.13	7.52

[1] Old system. [2] New system.

Table showing Comparison of Lawrence Sewage with the Sewage of Various English Communities.

[Parts per 100,000.]

Place.	Ammonia.		Place.	Ammonia.	
	Free.	Albuminoid.		Free.	Albuminoid.
Lawrence, ...	3.84	0.71			
Accrington, ...	5.18	0.68	York, ...	2.58	0.83
Birmingham, . . .	3.67	0.98	Chorley, ...	4.90	1.01
Leeds, ...	2.60	0.80	Heywood, ...	3.37	0.83
Manchester, ...	2.27	0.51	Average, . . .	3.40	0.85
Rochdale, ...	4.16	1.29			
Sheffield, ...	2.61	0.76			

In the early work at the Lawrence Experiment Station it was the custom to make, in the course of the regular analysis of sewage, determinations of the total solid matter, loss on ignition, etc.; also determinations of the solid matter in solution. For some years these determinations were omitted, however, from the regular analyses, but were begun again in 1902. A table on page 267 shows the results of this work.

In the following chapters of this report there is much discussion of the character of matters in solution and in suspension in sewage. From the facts elaborated it becomes clear that filtration is largely a process of oxidation of the organic matters in solution in sewage, and that a polluted, putrescible liquid is changed thereby to one containing little unoxidized organic matter, and, therefore, inoffensive. Although much of the solid organic matter is oxidized and disposed of during filtration, the stable carbonaceous character of other portions of the suspended matter in sewage is clearly set forth. Any process of treatment, therefore, by which suspended matter can be removed before filtration will prevent filter clogging, and allow higher rates of filtration per unit area of filter; in other words, the capacity of a sewage filter to do efficient work may be said to be in inverse proportion to the amount of matters in suspension in the sewage. The economical bearing of this fact where a limited area only is available for filtration purposes is evident. In a subsequent section attention is drawn to the fact that the age of a sewage is an important factor in its purification. Fresh sewage contains larger particles of organic matter in suspension than older

sewage and causes more clogging at the surface of sand filters, while the finer particles in older sewage pass into the body of the filter, there accumulate and cause subsurface clogging. Other changes going on during the aging of sewage also affect its subsequent filtration. These will be described later in a chapter dealing with the septic tank. The methods investigated at the station for the removal of suspended matter from sewage have been as follows: (1) sedimentation; (2) chemical precipitation; (3) straining through coke or coal; (4) the septic tank system; (5) preliminary rapid filtration with partial oxidation. The results of these studies are presented in a subsequent chapter.

Average Yearly Analyses of Station Sewage.

[Parts per 100,000.]

Year.	Temperature (Deg. F.).	Ammonia.				Chlorine.	Oxygen[1] Consumed.
		Free.	Albuminoid.				
			Total.	In Solution.	In Suspension.		
1888,	53	1.55	0.69	.16	.53	5.19	-
1889,	54	1.84	0.55	.29	.26	4.92	-
1890,	54	1.82	0.69	.38	.31	5.45	3.25
1891,	54	2.22	0.73	.34	.39	7.37	3.64
1892,	55	2.45	0.75	.34	.41	8.33	4.22
1893,	54	2.68	0.63	.31	.32	8.57	3.45
1894,	53	3.43	0.63	.26	.37	8.07	3.54
1895,	55	4.05	1.00	.28	.72	11.43	5.10
1896,	55	4.08	0.78	.31	.48	10.12	4.14
1897,	55	3.82	0.80	.38	.42	8.48	3.90
1898,	56	2.89	0.58	.29	.29	7.07	3.22
1899,	56	3.08	0.59	.26	.33	6.60	4.01
1900,	56	4.19	0.67	.30	.37	8.86	4.21
1901,	57	4.54	0.75	.35	.40	10.03	4.51
1902,	55	4.49	0.72	.31	.41	10.11	4.06
1903,	57	4.39	0.59	.30	.29	10.12	3.98
1904,	58	5.15	0.95	.47	.48	12.31	4.86
1905,	58	3.42	0.58	.32	.26	8.64	3.68
1906,	54	3.55	0.58	.31	.27	6.67	4.07
1907,	52	4.75	0.85	.40	.45	15.42	7.07 [1]
1908,	55	4.17	0.66	.34	.32	14.30	5.57

[1] Method changed at the beginning of 1907 to coincide with method used in State House laboratories.

Average Yearly Analyses of Lawrence Street Sewage.

[Parts per 100,000.]

Year.	Temperature (Deg. F.).	Ammonia.				Chlorine.	Nitrogen as —		Oxygen Consumed.
		Free.	Albuminoid.				Nitrates.	Nitrites.	
			Total.	In Solution.	In Suspension.				
1894,	55	2.84	1.00	.61	.39	8.85	.090	.0109	5.59
1895,	57	2.64	0.98	.54	.43	11.94	.181	.0148	6.54
1896,	58	3.62	1.16	.71	.45	13.34	.184	.0263	6.49
1897,	60	3.19	1.26	.78	.48	13.36	.184	.0182	7.59
1898,	59	2.60	1.00	.67	.34	10.38	.201	.0197	7.20
1899,	60	3.47	1.02	.58	.44	11.90	.156	.0185	9.02
1900,	61	3.41	0.97	.56	.41	11.81	.141	.0135	9.25
1901,	60	3.12	0.92	.57	.35	11.05	.185	.0224	8.05
1902,	59	2.62	0.88	.55	.33	13.54	.198	.0296	7.79
1903,	59	2.15	0.72	.44	.28	11.21	.146	.0142	8.41
1904,	60	2.44	0.99	.58	.41	11.63	.117	.0126	9.61
1905,	62	2.54	0.91	.57	.34	12.78	.086	.0146	9.30
1906,	62	2.53	0.99	.53	.46	14.20	.088	.0115	11.53
1907,	58	2.47	0.97	.56	.41	13.80	.090	.0108	11.80
1908,	60	2.60	0.88	.53	.35	13.76	.100	.0099	9.77

Average Yearly Analyses of Sewage applied to Filters Nos. 1, 6 and 9A.

[Parts per 100,000.]

Year.	Free Ammonia.			Albuminoid Ammonia.			Chlorine.			Oxygen Consumed.		
	Filter No. 1.	Filter No. 6.	Filter No. 9A.	Filter No. 1.	Filter No. 6.	Filter No. 9A.	Filter No. 1.	Filter No. 6.	Filter No. 9A.	Filter No. 1.	Filter No. 6.	Filter No. 9A.
1888,	1.55	-	-	.69	-	-	5.19	-	-	-	-	-
1889,	1.84	-	-	.55	-	-	4.92	-	-	-	-	-
1890,	1.82	-	-	.69	-	-	5.45	-	-	3.25	-	-
1891,	2.22	-	-	.78	-	-	7.87	-	-	3.64	-	-
1892,	2.58	3.04	2.79	.81	.99	.80	8.05	9.40	8.42	4.40	5.51	4.52
1893,	2.75	3.04	2.88	.68	.72	.69	7.81	7.47	7.39	3.61	4.49	3.62
1894,	3.65	3.66	3.66	.72	.74	.68	8.79	9.22	8.48	4.02	3.81	3.68
1895,	4.29	4.05	4.29	.74	.68	.78	11.78	10.09	9.91	4.78	4.00	3.55
1896,	4.10	4.60	4.10	.71	.84	.66	9.70	9.24	7.79	3.64	3.99	3.42
1897,	4.03	4.02	4.06	.80	.84	.85	7.20	7.69	7.05	3.67	3.95	4.09
1898,	3.29	3.28	2.69	.77	.69	.62	6.17	6.57	5.84	4.11	3.58	3.20
1899,	3.52	3.11	2.88	.70	.65	.67	8.32	8.12	7.44	4.68	4.33	4.04
1900,	4.26	4.42	4.43	.71	.68	.77	9.57	9.30	9.35	4.67	4.44	4.84
1901,	4.60	4.69	4.60	.79	.80	.89	11.45	10.81	10.75	5.20	4.92	4.92
1902,	4.26	4.26	4.26	.71	.71	.71	10.70	10.70	10.70	4.53	4.53	4.53
1903,	4.36	4.36	4.36	.61	.61	.61	11.17	11.17	11.17	4.43	4.43	4.43
1904,	4.54	4.54	4.54	.72	.72	.72	12.06	12.06	12.06	4.97	4.97	4.97
1905,	3.11	3.11	3.11	.51	.51	.51	8.16	8.16	8.16	3.64	3.64	3.64
1906,	4.72	4.72	4.72	.72	.72	.72	12.91	12.91	12.91	5.04	5.04	5.04
1907,	4.13	4.13	4.13	.76	.76	.76	11.13	11.13	11.13	5.70	5.70	5.70
1908,	2.61	2.61	2.61	.47	.47	.47	9.04	9.04	9.04	3.40	3.40	3.40

Average Solids.

Station Sewage.

[Parts per 100,000.]

Date.	Unfiltered.			Filtered.			In Suspension.		
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1887-89,[1]	56.5	24.3	32.2	33.4	10.7	22.7	23.1	13.6	9.5
1902,[2]	73.2	34.2	39.0	52.4	18.3	34.1	20.8	15.9	4.9
1903,[3]	66.1	30.6	35.5	47.2	17.4	29.8	18.9	13.2	5.7
Regular Sewage.									
1906,	69.6	27.3	42.3	58.1	19.3	38.8	11.5	8.0	3.5
1907,	81.8	32.9	48.9	58.0	16.3	41.7	23.8	16.6	7.2
1908,	71.7	28.7	43.0	56.8	17.4	39.4	14.9	11.3	3.6
Settled Sewage.									
1906,	61.7	21.7	40.0	55.8	16.8	39.0	6.0	4.9	1.1
1907,	65.3	22.5	42.8	54.6	14.8	39.8	10.7	7.7	3.0
1908,	60.2	19.8	40.4	54.4	15.3	39.1	5.8	4.5	1.3
Andover Regular Sewage.									
1905,	58.1	35.4	22.7	32.7	14.5	18.2	25.4	20.9	4.5
1906,	49.9	28.2	21.7	31.0	12.9	18.1	18.9	15.3	3.6
1907,	47.3	24.3	23.0	33.8	12.5	21.3	13.5	11.8	1.7
Andover Settled Sewage.									
1905,	44.5	22.5	22.0	36.9	16.0	20.9	7.6	6.5	1.1
1906,	35.6	16.0	19.6	31.5	12.9	18.6	4.1	3.1	1.0
1907,	42.0	18.6	23.4	35.4	13.1	22.3	6.6	5.5	1.1
1908,	56.5	25.4	31.1	51.1	21.0	30.1	5.4	4.4	1.0
Sewage Applied to Strainer E.									
1902,	70.7	32.9	37.8	50.6	17.7	32.9	20.1	15.2	4.9
1903,	66.0	30.8	35.2	49.6	17.4	32.2	17.9	13.4	4.5
Effluent of Strainer E.									
1902,	50.4	18.8	31.6	45.8	16.2	29.6	4.6	2.5	2.1
1903,	53.4	21.7	31.7	43.9	15.1	28.8	9.5	6.6	2.9
Sewage Applied to Coal Strainer F.									
1902,	72.1	32.2	39.9	53.0	17.3	35.7	19.0	14.9	4.1
Effluent of Coal Strainer F.									
1902,	63.7	26.2	37.4	52.7	18.0	34.7	11.0	8.3	2.7

[1] December to October, inclusive.
[2] July 1 to December 31, inclusive.
[3] January 1 to December 31, inclusive.

SAND AND SOIL FILTRATION, ETC.

In all, 193 filters have been operated as intermittent filters for the purification of sewage during the whole or part of their history. Of these, 156 have been constructed of sand, and have varied in depth from 10 inches to 10 feet and in size of material from 0.04 millimeter to 0.48 millimeter effective size. Of a similar type were 7 filters constructed of gravel stones of various sizes. Of the remaining intermittent sewage filters, 8 were constructed of coke breeze, 9 of cinders or ashes, 2 of garden soil, 4 of mixtures of peat and sand, 1 of sand and iron ore, 1 of sand and iron filings, 2 of a mixture of sand and marble chips, 1 of stone and iron filings and 2 of iron turnings. A number of these filters have been operated with sewage of different characters at different periods of their history, the classification according to the applied sewages being as follows: 74 filters have been operated with untreated Lawrence sewage, 3 with concentrated sewage, 4 with clarified settled sewage, 2 with chemically clarified sewage, 3 with strained sewage, 15 with septic sewage and 15 with the effluents from other filters. In addition, 59 filters have been operated either with raw or treated manufacturing wastes, 15 with sewage containing various germicides, 2 with sewage which had been sterilized by heat, 4 with sewage from two municipal areas, 7 in connection with studies on prenitrification and 9 in connection with studies on the removal of clogging material.

At the present time 4 sand filters started in December, 1887, or January, 1888, 1 started in October, 1890, and 1 started in July, 1894, are still in operation. Most of the sand filters, however, including several now in operation, have been operated for shorter periods than the filters named, these periods varying from a few months to a number of years, as the studies involved seemed to demand. Of the greatest importance in the operation of such sand filters is the grade of sand most efficient in producing a satisfactory purification of the sewage applied; next in interest is the rate at which such filters can be operated with good results; and third, the permanence of such filters, or their capacity for receiving sewage daily for many years without deterioration or undue clogging of the main body of the filter. Besides these three subjects of primary importance in the operation of sand sewage filters, numerous other points of secondary importance are discussed in this report.

In 1887, 9 wooden tanks about 17 feet 4 inches in diameter at the top, or $\frac{1}{200}$ of an acre in area, and 6 feet deep, were filled to certain depths with various sands, soils, etc., common to New England, and, as stated, several of the filters started in these tanks are still in good

operation. In tank, or Filter, No. 1 was placed 5 feet in depth of clean, coarse sand of an effective size of 0.48 millimeter; Filter No. 2 was made of 5 feet in depth of fine, white sand having an effective size of 0.08 millimeter; Filter No. 3 was 5 feet in depth and made of peat which is nearly all vegetable matter; Filter No. 5 consisted of 5 feet in depth of an excellent quality of brown soil taken from a garden which had been cultivated a number of years; Filter No. 6 was 3 feet 8 inches in depth of a mixture of coarse and fine sand and gravel; Filter No. 7 was of this same mixture of sand and gravel, of the same depth, and over this was placed 10 inches of yellow, sandy loam, then 6 inches in depth of brown soil; that is, this filter represented the common soil, subsoil and undergravel or sand so common in New England; Filter No. 9 was made of 4 feet 3 inches in depth of clay hardpan covered with 9 inches of brown soil.

It is hardly necessary at this time to enter into a discussion of Filters Nos. 3, 5 and 9. It may be stated, however, that Filters Nos. 3 and 5 were put out of operation after periods of two and four years, respectively, as it had been proved during this period that the materials in these two filters were valueless for sewage purification, owing to their very fine character. This caused them to remain practically saturated with the sewage, and the entrance of air together with the necessary bacterial oxidation was prevented. In fact, a reducing action occurred in these filters and their effluents were at times of a poorer quality than the applied sewage. Filter No. 9, consisting of clay hardpan, would not allow a volume of water equal to the rainfall upon the area of the surface of the filter to pass through it, and although this filter was constantly covered with sewage, this sewage did not appear at its outlet pipe for nearly a year. In October, 1890, the clay hardpan was removed from Tank No. 9 and in this tank was placed, above the usual underdraining materials, 5 feet in depth of sand having an effective size of 0.17 millimeter. This filter, known as Filter No. 9A, is still in operation. The material first placed in Tank No. 5, that is, garden soil, was removed in 1891, and in this tank have been placed from time to time other materials.

During the first years of the station a tenth tank, of the size mentioned above, was used in experiments upon the evaporation of water, but in July, 1894, this tank was filled with 5 feet in depth of coarse and fine sand, similar to that in Filter No. 6, and having an effective size of 0.36 millimeter. The filter was designated Filter No. 10. All the experimental filters here mentioned had, placed beneath the sand, 6 inches in depth of gravel and also wooden underdrains, but into this filter no gravel or underdrains were put except directly above the outlet near one side of

the tank. A partition extending 3 feet below the surface was placed in the sand of this filter, separating the quarter of the surface which was farthest removed from the underdrains from the remainder, and to this quarter all the sewage has been applied. This filter is still in operation.

Each of the filters mentioned here was intended to represent natural conditions of soil and sand existing in Massachusetts, and the primary object in view was to determine the suitability of these soils or sands for use as filtration areas for the purification of sewage. As already stated, it was soon ascertained that the fine grained materials, such as loam, clay and peat, were practically valueless for this purpose, since when flooded they did not admit air, and were, in fact, almost impervious to water. With porous materials it was found that different treatment was required for each. The volume of sewage which each material would take daily or weekly, the size of the dose of sewage that could be applied at one time with the best results, and the frequency of application, were the first subjects thoroughly studied. Briefly stated, intermittent sand filtration requires that the sewage shall pass at a slow rate over particles of sand in an atmosphere containing free oxygen, that is, the filter shall be so operated that the space between the sand grains shall always contain both sewage and oxygen. In practice this apparently simple problem is complicated by many variables which tend to modify the successful operation of a filter. The chief variables are the effective size[1] of the sand, its uniformity, the strength of the sewage and amount of suspended matter, the condition of the sewage, whether fresh or stale, and the temperature of the air. The satisfactory action of a filter, as well as its permanency or life, depends upon the proper adjustment of these varying conditions. It is absolutely necessary that the interstitial spaces of the filter shall always contain free oxygen.

Purification Results obtained by Intermittent Sand Filtration during Twenty-one Years by Filters Nos. 1, 2, 4, 6, 9A and 10, 1/200 of an Acre in Area, with Results also of Filters Nos. 5, 5A, 5B, 5C, 7, 305 and 306.

The first investigations at Lawrence were directed towards the purification of sewage in the truest sense, that is, the removal or oxidation of all or nearly all organic matter; but it was found, as early as 1889, that filters of stone could be operated at high rates and a good nitrification of the applied sewage obtained, although, as explained in the report of 1890, the effluents of such filters differ widely from those of

[1] The effective size of a sand is the maximum diameter in millimeters of the finer 10 per cent. of the sand grains. (See article on "Physical Properties of Sands," report for 1892, pp. 539-556.)

sand filters in the amount of residual organic matter remaining in them. Those who speak of the advance shown in English work of a later date should realize that this English work was based on these experiments at Lawrence with coarse filtering material. Indeed, English authorities and all unprejudiced observers acknowledge this.[1] Moreover, when the early English filters of coke, etc., operated at rates of 500,000 gallons per acre daily, are spoken of as marking a great advance over sand filtration, the essential differences between these filters and sand filters are frequently overlooked. Sand filters purify sewage. Most of the coarse filters, on the other hand, operated at high rates simply produce a modified sewage which still contains a large amount of organic matter. They do, of course, if well constructed and operated, oxidize the putrescible matter and produce effluents that are stable and often high in nitrates, — effluents in every sense fit to be turned into many streams, especially after sedimentation, straining or other end treatments. Such filters are of great value and service for many communities, and various combinations of filters of different kinds are in use abroad, and to some extent in this country, in order to concentrate the disposal area in some instances, but generally where areas for sand filters cannot be found.

Sand filtration is, however, and for many years undoubtedly will be, the most important method of sewage purification in Massachusetts. The results, therefore, obtained during the past twenty-one years from the sand filters at Lawrence, especially from those operated for many years, are worthy of much study. As stated previously, there are in operation at the present time at Lawrence four filters started in the winter of 1887–88, one filter started in the fall of 1890 and one in 1894.

Nitrification and Strength of Applied Sewage.

Filters Nos. 1, 2, 4 and 6, put into operation in the winter of 1887-88, did not begin to show any considerable amount of nitrates in their effluents until the spring of 1888. Since that date, however, both winter and summer effluents of these filters have generally contained large amounts of nitrates, varying in the case of Filter No. 1 from an average of 0.80 part per 100,000 in 1888 to 4.29 parts in 1906; in the effluent of Filter No. 2 from 0.66 in 1888 to 4.46 in 1906; in the effluent of Filter No. 4 from 0.22 in 1888 to 4.62 in 1906; in the effluent of Filter No. 6 from 0.71 in 1888 to 4.25 in 1906; in the effluent of Filter No. 9A, started in the fall of 1890, from 1.32 in 1891 to 3.94 in 1906, and in the effluent of Filter No. 10, started in the summer of 1894, from 2.06 in 1907 to 3.34 in 1906. In a general way the degree of nitrification

[1] See chapter on "Sprinkling or Trickling Filters."

occurring in these filters has followed the strength of the sewage applied, the sewage pumped at the station varying from an average of 1.55 parts and 0.69 part per 100,000 of free and albuminoid ammonia, respectively, in 1888, to 5.15 parts and 0.95 part per 100,000, respectively, of free and albuminoid ammonia in 1904. During the first eight or nine years' operation of the station the strength of the sewage increased yearly; for several following years the average strength remained about stationary, and during the last ten or twelve years it has been on the average slightly weaker than in 1895 and 1896, although there have been occasional years, like 1904, when it has been stronger than in 1896 and 1897. Since 1895 the total amount of nitrogen in the sewage, determined as free and albuminoid ammonia, has been at least twice as great as that present during the first two or three years of operation of the station.

Rate of Operation.

The rates of operation of these 6 filters have varied considerably during different years. During the first three years of operation of Filter No. 1 the rate was increased from 53,400 gallons to 84,200 gallons per acre daily; then for a period of three years the rate of operation was more than 100,000 gallons per acre daily, with a maximum rate of 124,100 gallons in 1892. From 1894 to 1908, inclusive, the rate has been varied from a maximum of 72,000 gallons per acre daily in 1903 to a minimum of 50,700 gallons per acre daily in 1907. This filter, it will be remembered, contains 5 feet in depth of sand of an effective size of 0.48 millimeter. Filter No. 2, containing 5 feet in depth of sand with an effective size of 0.08 millimeter, trenched with coarse sand, has received sewage during its different years of operation in volumes varying from 28,200 gallons in 1888 to 50,800 gallons per acre daily in 1891. Filter No. 4, constructed of 5 feet in depth of river silt having an effective size of 0.04 millimeter, and trenched with coarse sand, has been operated at average rates of from 18,400 gallons in 1907 to 41,800 gallons per acre daily in 1892. Filter No. 6, containing 44 inches in depth of mixed coarse and fine sand and gravel, this mixture having an effective size of 0.35 millimeter, has been operated at rates varying from 38,800 gallons in 1908 to 85,500 gallons per acre daily in 1893. Filter No. 9A, containing 5 feet in depth of sand with an effective size of 0.17 millimeter, has been operated at rates varying from 111,700 gallons in 1893 to 48,800 gallons per acre daily in 1900. Filter No. 10, constructed of sand similar to that in Filter No. 6 has been operated at rates — taking into consideration only a quarter section of the surface to which sewage is applied —

varying from 83,600 gallons in 1905 to 160,000 gallons per acre daily in 1894. All of these rates for these filters are given year by year in the tables of annual results presented later. (See pages 290–292, inclusive.)

Protection from Winter Weather during Early Years.

Filters Nos. 1, 2, 4 and 6 when first put into operation were protected during the winter months by a canvas cover, and the trenches of Filters Nos. 2 and 4 were sometimes covered also with boards. During the winter of 1890–91 these filters were first left unprotected from the cold. Filter No. 1 during the winter of 1895–96, Filters Nos. 2 and 4 during the winter of 1892–93 and Filter No. 6 during the winter of 1893–94 were again covered with the canvas roof, but from those dates until 1904 they were left exposed to the winter weather. Since the winter of 1904–05 the filters have been trenched and these trenches covered with boards. This point will be discussed later.

Increased Rates, Sand Removal in 1892 and 1893, followed by a More Systematic Surface Treatment.

While all the filters were put into operation at a fairly moderate and reasonable rate, it was thought necessary, in order to learn the maximum rates at which such filters could be operated with good results and without undue clogging, to increase these rates, so that, in the course of four years, the rate of operation of Filter No. 1 had been more than doubled, that is, from 53,400 gallons to 115,800 gallons per acre daily. That of Filter No. 2 had been doubled also in two years, namely, from 28,200 gallons to 59,600 gallons per acre daily. The rate of Filter No. 4 was increased from 28,700 gallons in 1888 to 41,800 gallons per acre daily in 1892. Filter No. 6 had its rate increased from 39,500 gallons in 1888 to 61,200 gallons per acre daily in 1891. Following this increase of rate, the upper layers of each filter became badly clogged in 1891 and 1892, and it was considered necessary at that time (1892), and again in the spring of 1893, in order to get satisfactory results, to remove certain amounts of surface sand. The clogging, and the ensuing poor purification, was, moreover, intensified by the accumulation in some of the filters of organic matter in stratified layers, as noted below. (See page 297.)

From Filters Nos. 1 and 6, 9 and 4 inches in depth of sand respectively, were removed; from the trenches in Filter No. 2, 4½ inches and from the trenches of Filter No. 4, 3½ inches. From the spring of 1893, however, to the end of 1908, a period of nearly sixteen years, all these filters were operated without sand removal. This was accomplished, during a period of about seven years, by systematic raking

a number of times a year, meaning by raking not the removing of material, but the breaking up of the surface layers to a depth of 1 inch, similar to what is done on a large scale in harrowing. Each year, moreover, the upper 6 inches of Filters Nos. 1, 6, 9A, etc., were dug over twice, and occasionally the coarse sand in the trenches of Filters Nos. 2 and 4 was removed, the sides and bottoms of these trenches raked and scraped and the coarse sand then replaced. This removal and replacing was done five times with Filter No. 2 between the fall of 1893 and the fall of 1896. It was not done again until the fall of 1903. The new trenches of coarse sand made in 1904 were first treated in this way in 1907 and again in 1908. The record of Filter No. 4 is similar in this respect.

Poor Winter Results from 1900 to 1904, and the Remedy.

Following this method of operation, good purification results were generally obtained from all these filters up to and including the year 1900. Poor purification was shown by some of them during portions of 1891, 1892 and 1893, however, previous to the sand removal already noted. Again in the winter of 1894–95, results were unsatisfactory with some filters because they were allowed to rest in early winter weather, and nitrification was interrupted for a considerable period on this account. In December, 1900, the pipe through which sewage is obtained from one of the Lawrence sewers became broken, and for three weeks sewage could not be applied to these filters. Owing to this the sand became frozen to a considerable depth, nitrification again ceased and did not become well-established until the spring of the following year.

This was only one of the causes, however, of poor purification at this time. Subsequent to 1893 organic matter was accumulating slowly in the upper layers of each filter. This accumulation was of little moment in the warmer weather of the year, and nitrates in the effluents were very high each summer; but in the winter, when the filter was exposed without covering to the cold, a more complete freezing of the upper layers occurred than was the case when less organic matter was present. The sewage entered more slowly as a result, and less air was present than was necessary for good nitrification. In fact, after seven years' operation, the upper 6 inches of these filters had, since the last sand removal in 1893, become clogged again to about the same extent as in 1892–93. In the report for 1893, page 410, it was stated: "We shall consider the treatment of the upper layers of a sewage filter, say the upper 6 inches, under the heading of management of filters necessary for their successful operation, and regard the permanency of the filters as the ability of the main body of the sand, below the upper 6 inches,

under proper treatment to purify sewage for an indefinite time." It was not desired at this time, however, to remove this clogged layer, although this would have again caused the production of satisfactory effluents, as in 1892 and 1893, but to try further experiments along other lines of treatment. It was evident that disturbance to a depth of 6 inches at this period was not sufficient, owing to clogging to that depth. Consequently, in the fall of 1903 an attempt was made to improve the results by disturbing the filters to a slightly greater depth and so arranging the surface of Filters Nos. 1, 6 and 9A that the sewage instead of being applied to the whole surface was applied to a low area; that is to say, after digging over 9 inches deep approximately, 3 inches in depth of surface sand were removed from about two-thirds of the area of each of these filters and piled up on the remaining one-third of the area. The sewage was in this way applied to a smaller area, less ice formed upon the filters, frost entered less deeply, and somewhat better nitrification was obtained than during several previous winters. The effluents, however, were not comparable in organic purity with those obtained during winters in which the filters had been operated for a shorter period and had received much weaker sewage. Therefore, to improve further their physical condition, Filters Nos. 1, 6 and 9A, early in the spring of 1904, were ridged and trenched to a depth of about 10 inches. In Filters Nos. 2 and 4, which for many years had contained trenches filled with coarse sand to which sewage was applied, new trenches were dug and filled with clean, coarse sand. The old trenches of clogged and dirty sand were allowed to remain, but after the construction of the new trenches they had no sewage applied to them. The object of this surface arrangement was (1) to improve winter purification of sewage and (2) to allow the disuse or resting of large portions of the upper sand in each filter, in order that the organic matter stored upon this sand might be removed by bacterial oxidation. This subject of the storage and disappearance of nitrogen and other organic matter is discussed in the following chapter.

In the fall of 1904 the filters were leveled, trenched again, at right angles to the summer trenches, and these trenches covered with boards. At the municipal filtration areas of the State, most of which are trenched and ridged in preparation for winter, the trenches during a considerable portion of each winter are roofed with ice and often covered with snow. These ice roofs form in consequence of the application of large volumes of sewage at one point and the slow passage of sewage into the filters. They never form on the filters at the station, however, owing to complete underdrainage and the small volume of sewage that can be applied to so small a filter. On the other hand much ice had always formed upon and adhered to the surface sand when the filters had been left

untrenched and exposed to the cold weather. This ice had to be removed from time to time in order that the filters might be kept in operation. The station filters, moreover, had been still more exposed to the cold because of the custom of removing the snow falling upon them. On the contrary the snow upon the ice roofs of the trenches of the municipal filters served to keep the filters warmer than they otherwise would have been, and promoted satisfactory winter purification.

It is evident that the method of operation of the Lawrence filters during the winters when they were exposed to the weather was not so conducive to the production of efficient sewage purification as it would have been if ice coverings could have been formed, as at the municipal filters. The station filters were more exposed to the cold, owing to the treatment followed, than the municipal filters, and frost entered the upper layers to a depth of many inches. By covering the trenches with boards, however, experimental filters obtain a winter surface protection about equal to that of the municipal areas. Temperature readings taken when the filters are covered with snow have shown that, even when the outside air stands at zero the air under these snow roofs is frequently above freezing, and that after the application of sewage averaging 36° to 37° F. in temperature, the temperature under these roofs may be several degrees above freezing for hours. It has been noticed also that even in the coldest weather little or no frost is present in the bottom of trenches protected in this way. This winter protection was begun in the fall of 1904 and the average results have improved considerably, so that the results of the last four years have been as satisfactory, on the whole, as during any period of operation, if we except the first year or two, when the sewage applied was much weaker than during subsequent years, and when the filters were new and much organic matter was being stored within them.

Work in 1908 similar to that of 1888 and 1889.

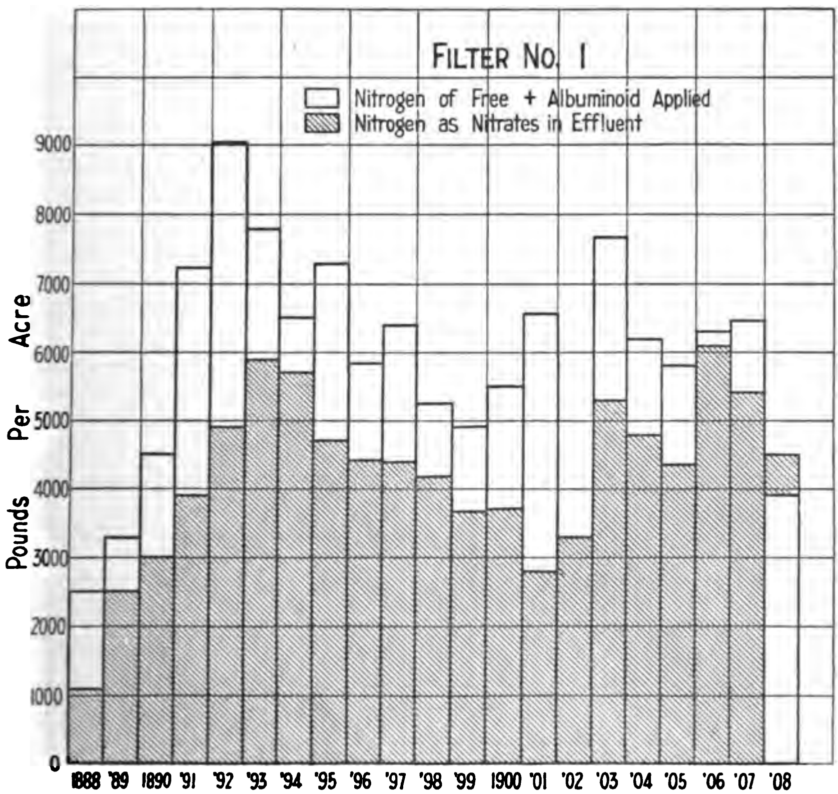
During the year 1908 an attempt was made to apply to Filters Nos. 1, 2, 4, 6, 9A and 10 sewage of about the same strength as that applied during the first or second year of operation of each filter, and at about the same rate. A study of following tables will show that the 1908 effluents compare quite favorably in degree of purity with those obtained during the first years of operation. A similar study of the tables of applied nitrogen and nitrogen changes, given on pages 317–321, inclusive, will show the following facts: —

Nitrogen Changes.

All filters stored a larger percentage of the applied nitrogen during their first years of operation than later, and the filters of fine sand

stored more than those of coarse sand. Not only did none of them have in their effluents so large a proportion of applied nitrogen oxidized in these first years as subsequently, but, also, all had less unoxidized nitrogen in their effluents, that is, the storage was greater. (See Diagrams Nos. 1–5.) It will be noticed also that during the last two or

Diagram No. 1.[1]



three years covered by this review the character of the effluents as regards the presence of unoxidized nitrogen is practically the same as that of the first two years. (See Diagrams Nos. 6–10.) Especially noticeable is the fact that the effluents of Filters Nos. 1 and 6 in 1908 and of Filters Nos. 2 and 4 in 1906, 1907 and 1908 contained as much or more nitrogen as nitrates than was applied as unoxidized nitrogen during these years.

[1] On Diagrams Nos. 1 to 5, inclusive, total column shows generally "nitrogen applied," while cross-hatched portion shows the part of total found as "nitrogen as nitrates," except when latter is greater than former, when total column shows "nitrogen as nitrates." The diagrams following are made on the same principle. On the diagrams the nitrogen of free + albuminoid ammonia equals total nitrogen; *i.e.*, the nitrogen found as albuminoid ammonia is multiplied by the factor necessary to show total organic nitrogen.

Diagram No. 2.

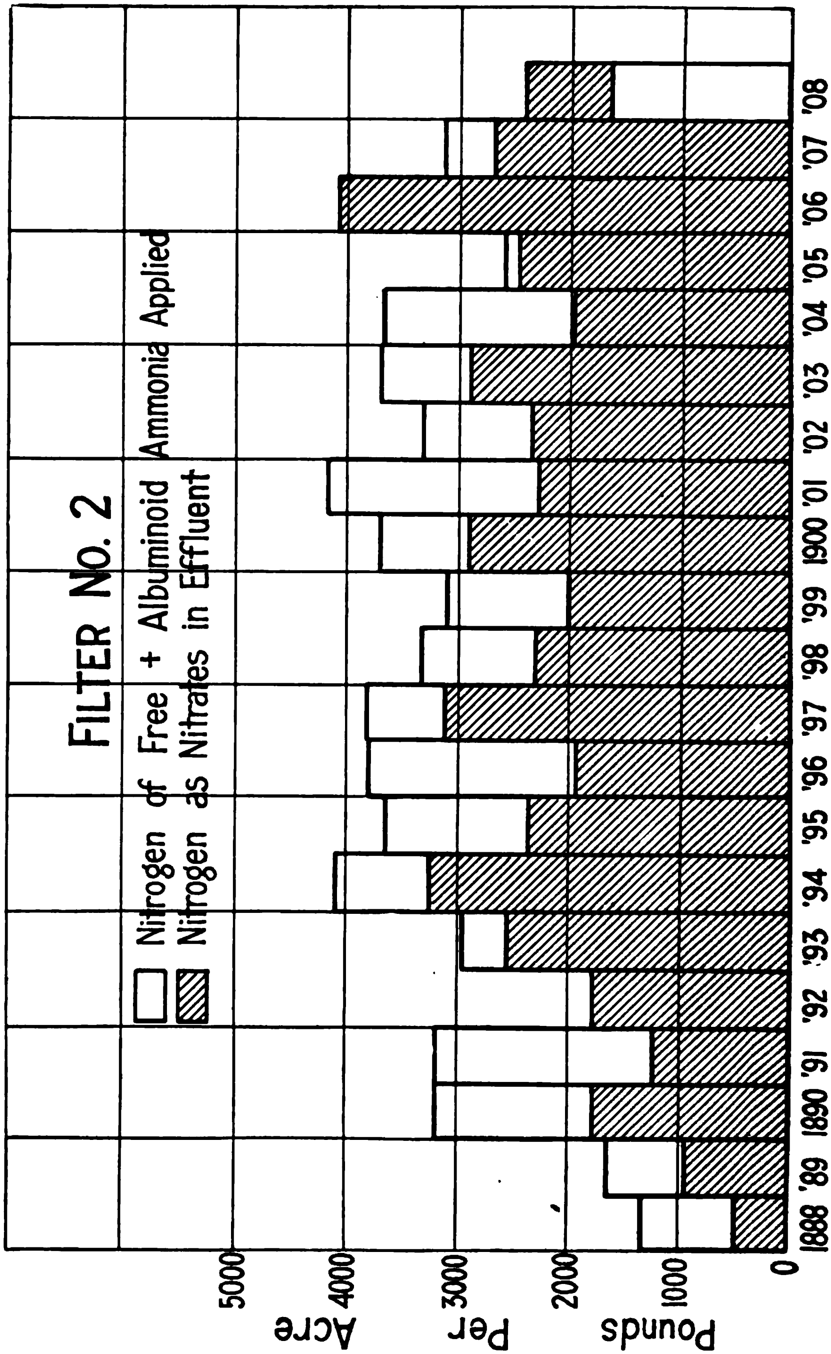
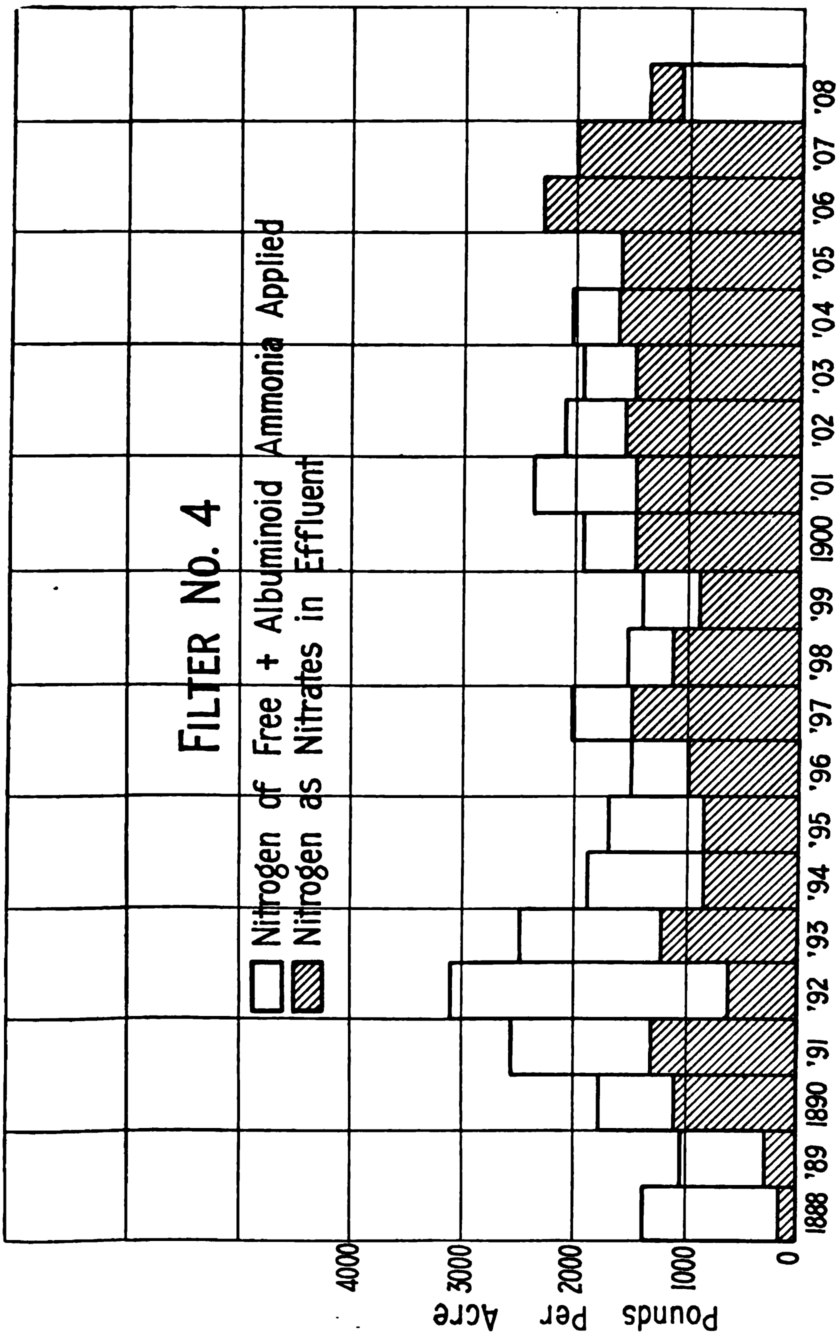
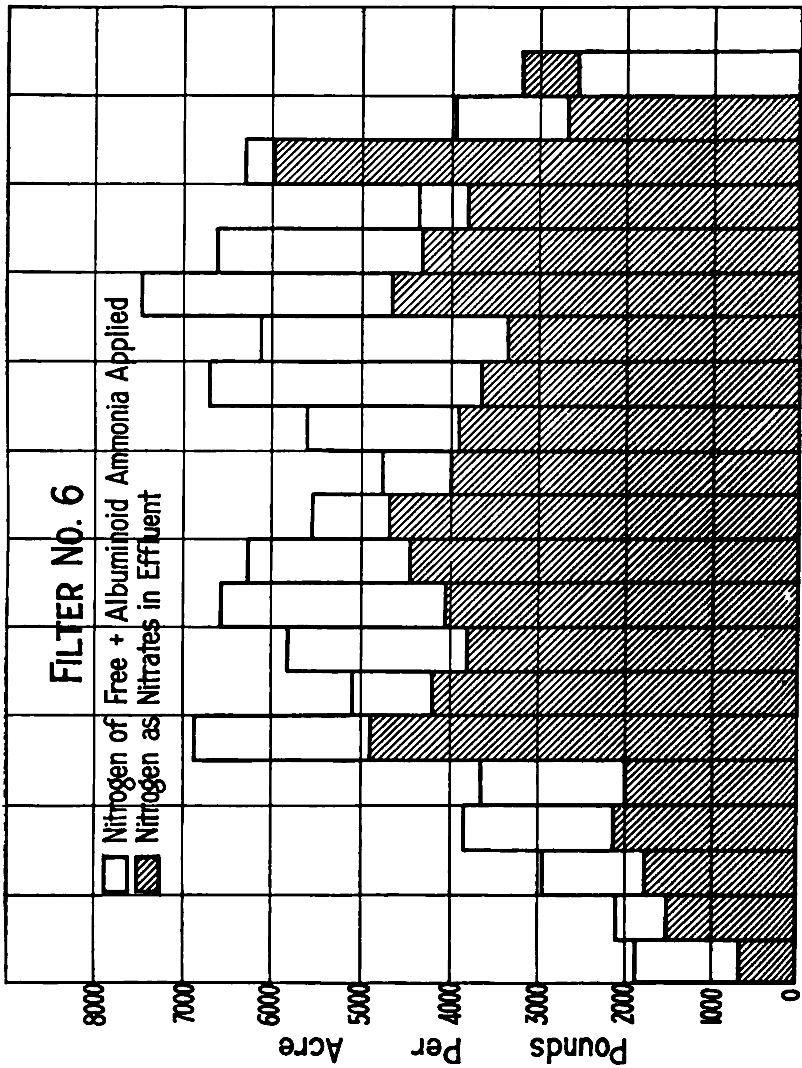

FILTER No. 2
Nitrogen of Free + Albuminoid Ammonia Applied
Nitrogen as Nitrates in Effluent
Pounds Per Acre
0
1000
2000
3000
4000
5000
1888 '89 1890 '91 '92 '93 '94 '95 '96 '97 '98 '99 1900 '01 '02 '03 '04 '05 '06 '07 '08

Diagram No. 3.


FILTER NO. 4
Nitrogen of Free + Albuminoid Ammonia Applied
Nitrogen as Nitrates in Effluent
Pounds Per Acre
0
1000
2000
3000
4000
1888
'89
1890
'91
'92
'93
'94
'95
'96
'97
'98
'99
1900
'01
'02
'03
'04
'05
'06
'07
'08

This shows that, in addition to the nitrogen applied, these filters were able to relieve themselves of some of the nitrogen stored during previous years. Filter No. 5C, started in 1905 with the purpose of maintaining as

Diagram No. 4.

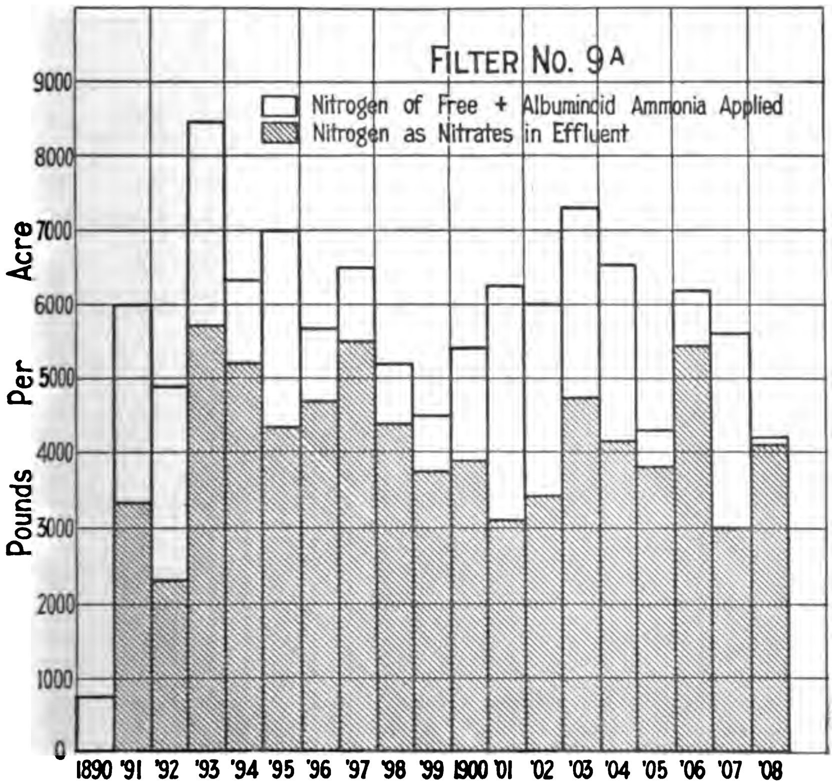


nearly as possible an equilibrium between applied nitrogen and nitrogen in its effluent, has, according to analyses, relieved itself continually during 1906, 1907 and 1908 of nitrogen stored during 1905. These facts are given in detail in the tables and diagrams on pages 277–322, inclusive.

Other filters, really in the same class as those just discussed, are considered separately. These filters are Nos. 5, 5A, 5B, 5C, 7, 305 and 306.

Filter No. 5. — This filter, 5 feet in depth and constructed of soil so fine that it kept itself always saturated with water, almost to the exclusion of air, was kept in operation from the beginning of 1888 until Aug. 24, 1891. Owing to the absence of air in the pores of the filter, the sewage was not oxidized, as happens with more open materials, but

Diagram No. 5.

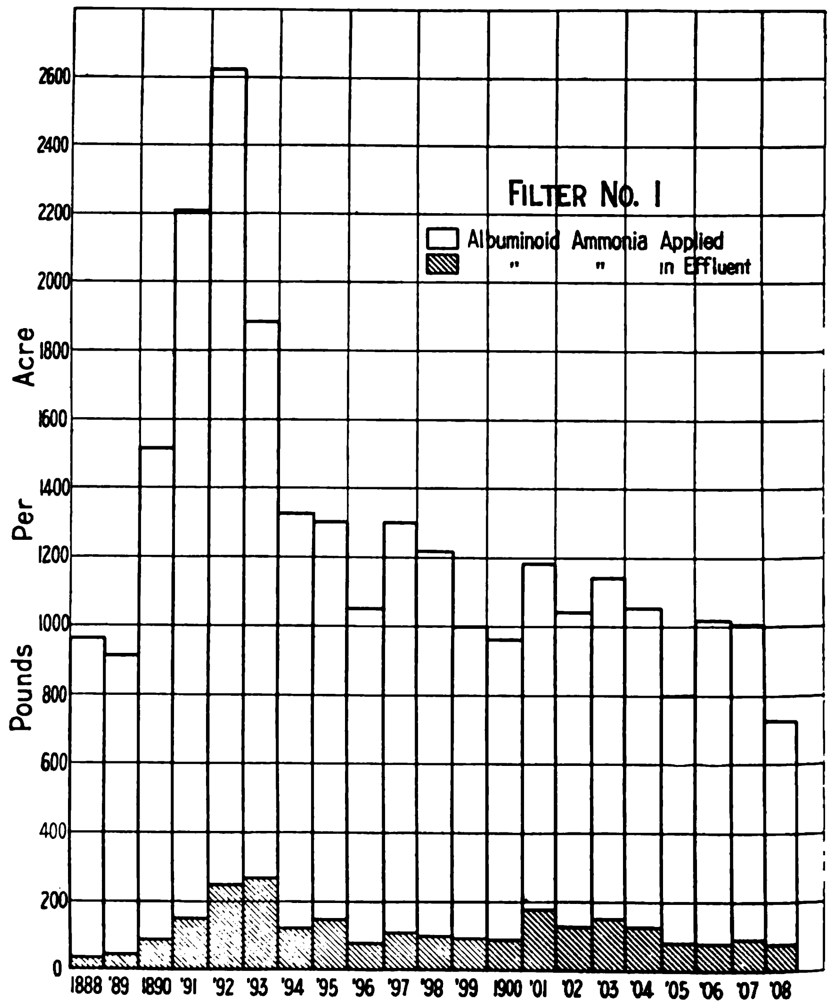


was merely strained, with the result that the insoluble organic matters and a very large percentage of bacteria were removed. Owing to the lack of oxygen, large amounts of iron were taken from the soil by the sewage, and the effluent was uniformly deep red in color, rapidly depositing ferric oxide on exposure to the air. The average rate of filtration was about 5,000 gallons per acre daily.

Filter No. 5A. — In September, 1891, the soil in Tank No. 5 was replaced by a sifted material coarser than Filter No. 1 sand and having

an effective size of 1.40 millimeters. This filter started at the rate of 17,100 gallons, and increased to nearly 70,000 gallons per acre daily before the end of the year. It was continued in operation until March 3,

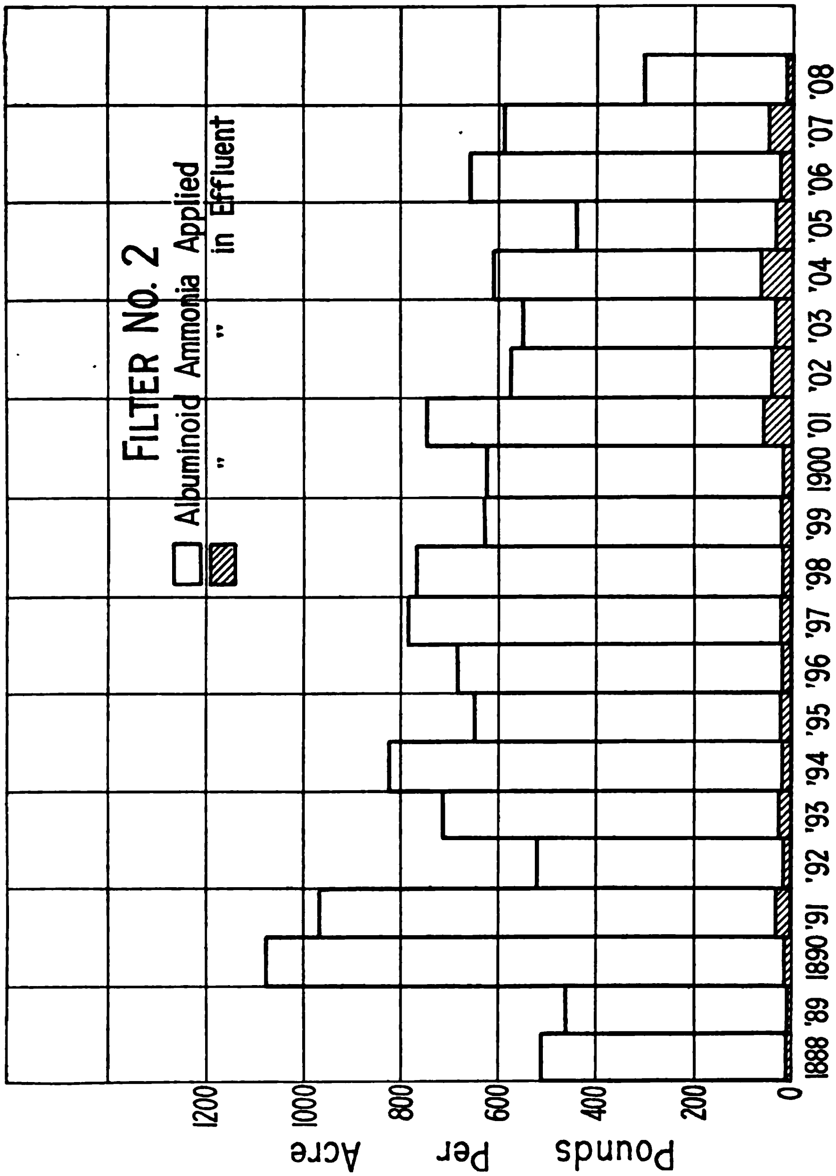
Diagram No. 6.



1898. It received during this period 816,970 gallons of sewage, equivalent to 163,394,000 gallons per acre. It was operated at an average rate of about 60,000 gallons per acre daily, and while its effluent, because of the coarseness of the filtering material, was never of the degree of purity obtained by some of the other filters, the degree of purification was good. When the experiment ended the filtering material was in good

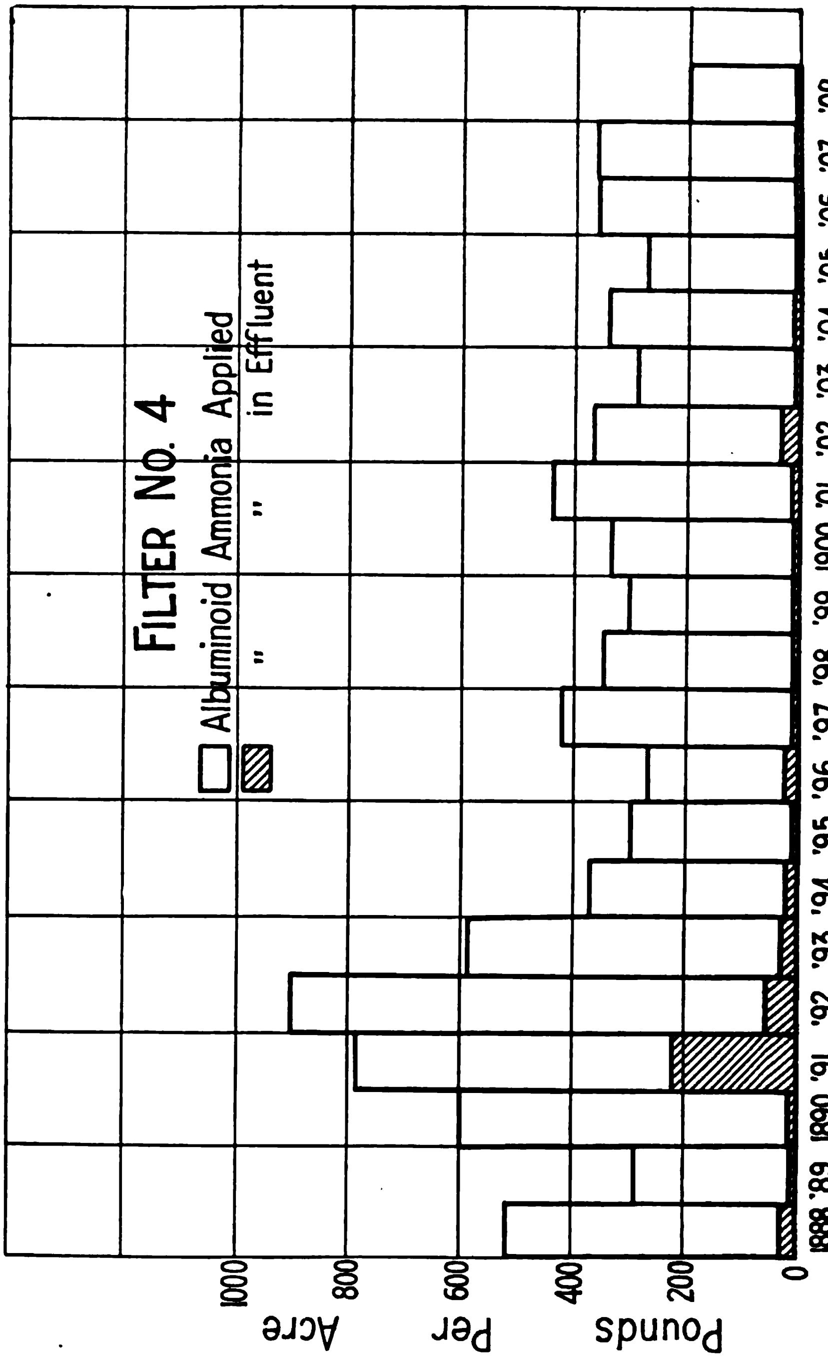
condition, and apparently capable of receiving sewage for an indefinite period of time.

Diagram No. 7.



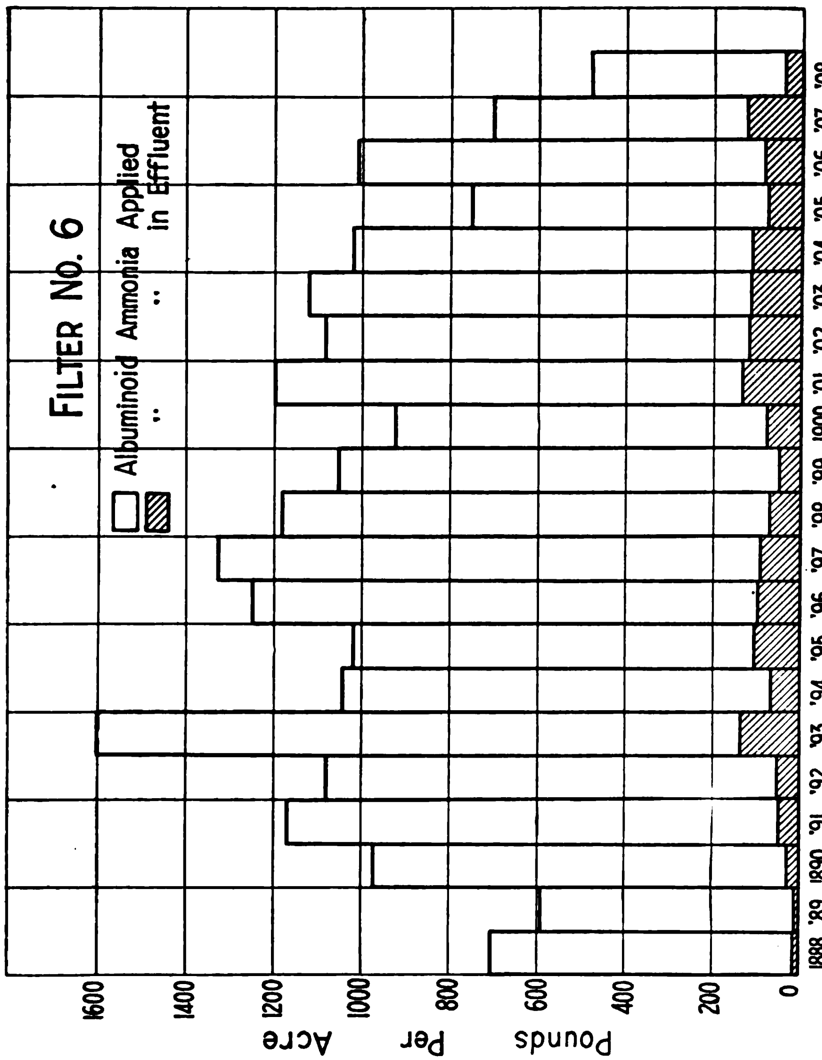
Filter No. 5B. — This filter, $\frac{1}{200}$ of an acre in area and constructed of 60 inches in depth of a mixture of cinders and ashes from the combustion of soft coal, was put into operation March 5, 1898. It

Diagram No. 8.


FILTER No. 4
Albuminoid Ammonia Applied
" " in Effluent
Pounds Per Acre
0
200
400
600
800
1000
1888 '89 1890 '91 '92 '93 '94 '95 '96 '97 '98 '99 1900 '01 '02 '03 '04 '05 '06 '07 '08

was operated during that year at a rate of 73,000 gallons per acre daily, and was continued in operation until July 11, 1905. During this time it gave an almost uniformly well-nitrified effluent, but not of the degree

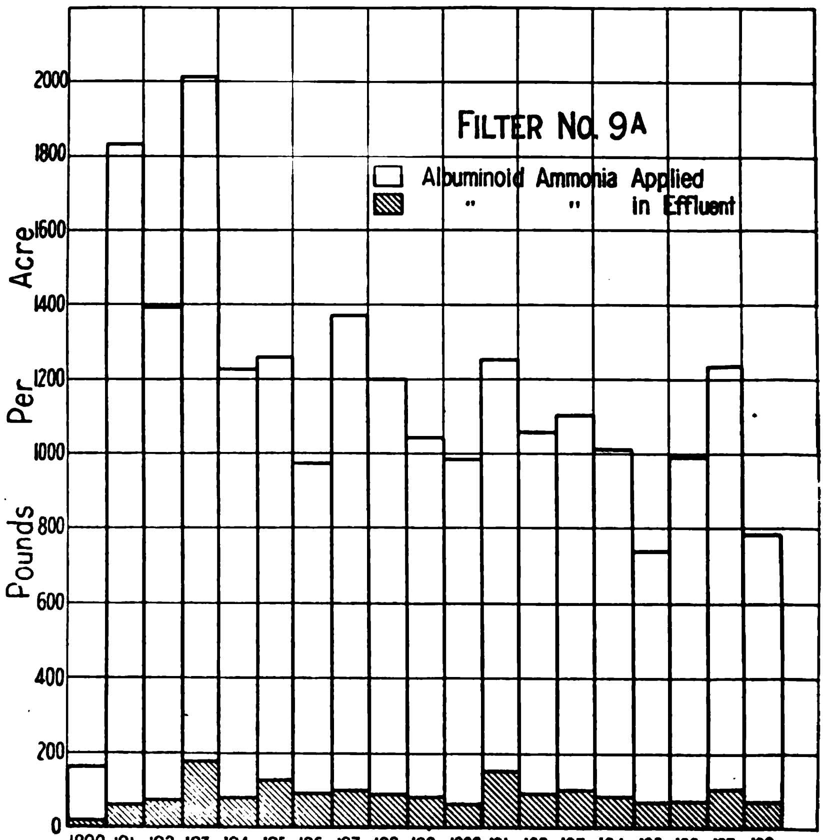
Diagram No. 9.



of purity obtained by filtration of sewage through good sand filters. It was operated at an average rate of 92,900 gallons per acre daily, and when stopped was apparently in a condition to receive sewage indefinitely.

Filter No. 5C. — This filter, started July 20, 1905, was constructed of 5 feet 2 inches in depth of coarse sand of an effective size of 0.22 millimeter. It is still in operation, and has received sewage at an average rate of 49,600 gallons per acre daily. The chief object in the operation of this filter has been to study the maintenance of the rate of a

Diagram No. 10.



sand filter at such a point that the organic matter in the applied sewage shall be as thoroughly oxidized as possible, and hence the filter was run year after year without undue clogging from the accumulation of organic matter, such as occurs in filters receiving sewage at so high a rate that the nitrogenous and other organic matter is greater than can be cared for by bacterial oxidation. The average analyses of the effluent of this filter for its period of operation are given in a following table.

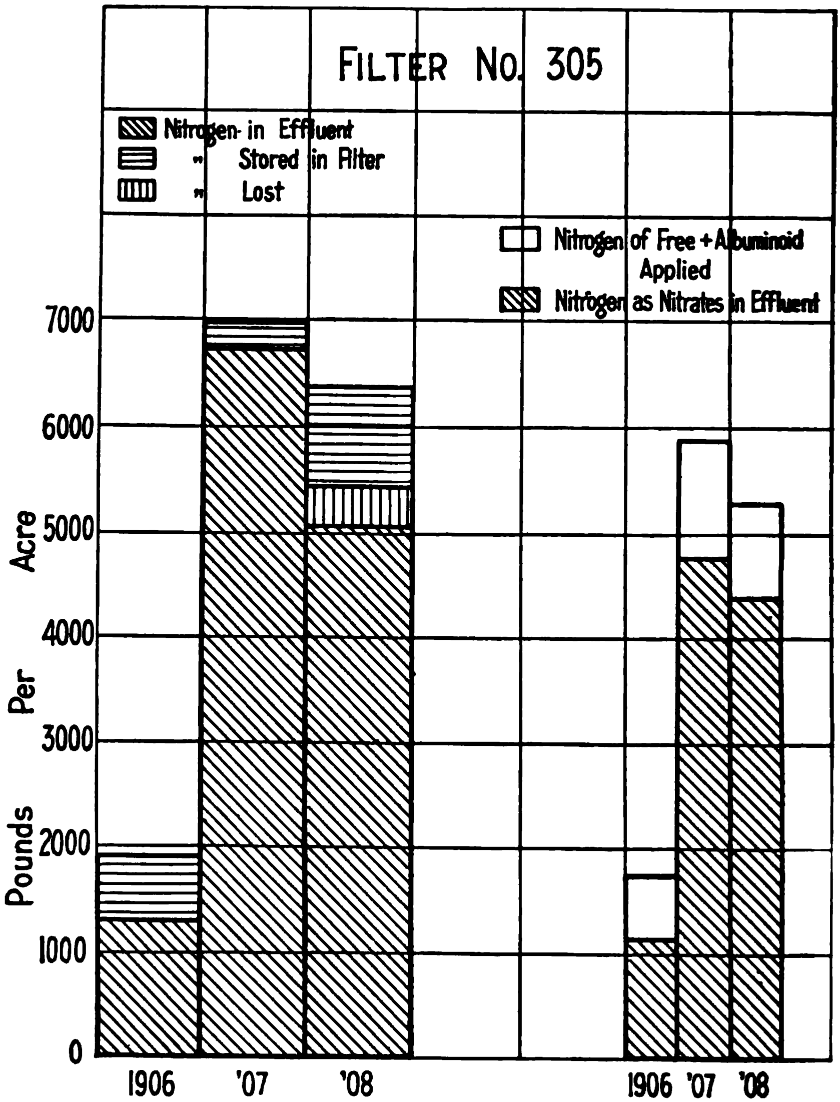
Filter No. 7. — This filter contained 44 inches in depth of sand similar to that in Filter No. 6, above which were put 10 inches of loam

and 6 inches of soil. In June, 1889, a circular trench, 3½ feet deep and 2 feet wide, was dug in this filter, and in this trench coarse gravel-stones were placed to a depth of 2 feet. In this gravel was placed a 6-inch drain-pipe with open joints once in 2 feet; the top of the pipe was level and even with the top of the gravel. Above were placed 17 inches of loam and soil. Sewage was introduced through a vertical pipe from the surface, and on Oct. 21, 1889, this pipe was trapped, preventing the passage of air except through the loam and soil. The volume of sewage applied, beginning October, 1889, was at the rate of 25,700 gallons per acre daily with uniformly good results. On Sept. 8, 1890, the volume was increased to 34,300 gallons per acre daily. Following this the effluent deteriorated in quality, and the volume applied was reduced, April 6, 1891, to 17,100 gallons per acre daily. This rate of filtration was followed through the first seven months of 1892 with good results. In July, 1892, it was found that the pipe was practically filled with sludge. This pipe was removed, cleaned and replaced, and the filter again started, at the rate of 34,000 gallons per acre daily. Up to the time of cleaning, sewage had been applied to the filter through this pipe for three years, that is, from June 25, 1889, to Aug. 1, 1892, the total quantity applied being 125,000 gallons, equivalent to 25,000,000 gallons per acre. Of the organic nitrogen applied during this period 22 per cent. was found in the pipe at the time of cleaning. On Jan. 1, 1893, the rate of operation was increased to 40,000 gallons per acre daily, but nitrification was found to be very incomplete and the effluent poor. On March 15 of this same year the rate was reduced to 20,000 gallons per acre daily, but as a reducing action appeared in the filter, it became evident that the filter was overdosed, or that the pipe was again filled with sludge. The pipe was again dug up, on April 26, and found to be more than half filled with sludge. Analyses showed that this sludge contained about 75 per cent. of the organic nitrogen applied since the pipe was last cleaned. This pipe was relaid and sewage again applied at the rate of 40,000 gallons per acre daily, but the pipe gradually clogged and the rate of operation had to be reduced from time to time. Owing to this frequent filling of the pipe, the filter was discontinued July 7, 1893, it having been proved that subsurface filtration of sewage was hardly successful under the conditions named.

Filters Nos. 305 and 306. — These 2 filters were started Aug. 24, 1906, and each contains 54 inches in depth of sand of an effective size of 0.27 millimeter and is 1/400 of an acre in area. We have here an opportunity to study, side by side, filters operated at the same rate and in the same manner, one receiving, however, strong sewage and the other sewage approximately one-half as strong. A study of Diagram No.

12 shows clearly that Filter No. 306 has been able to care for all, or practically all, the nitrogen applied, the amount not exceeding in any year 3,400 pounds per acre. The rate of operation of all these filters

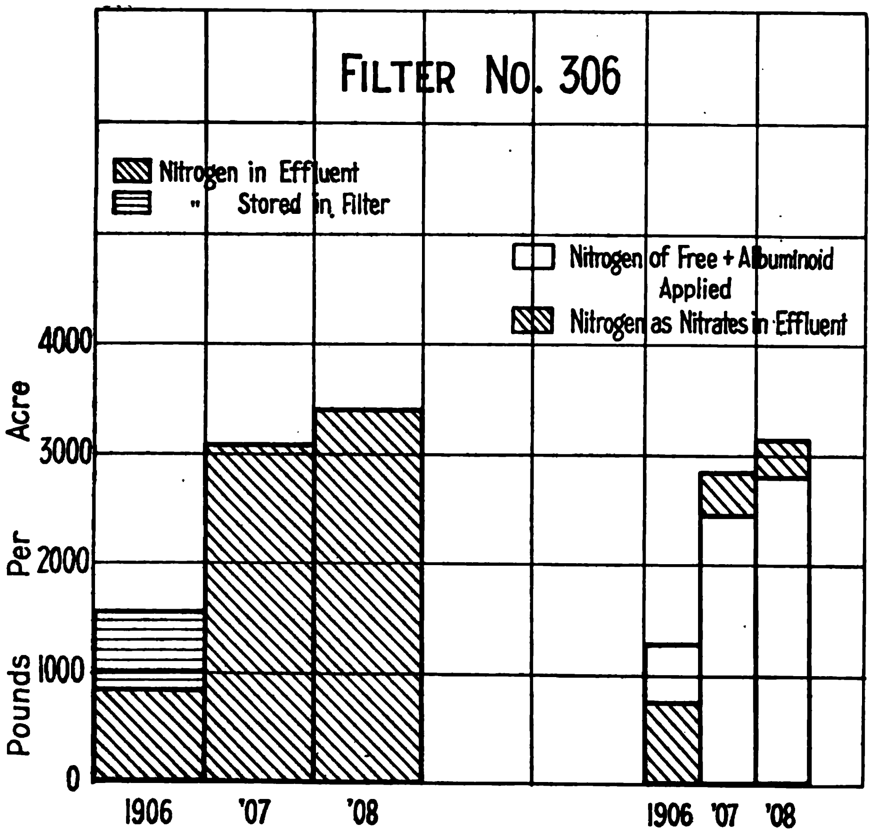
Diagram No. 11.



during each year since they were started is shown in following tables, which give also average analyses of their effluents. It will be seen that the effluent of the filter (No. 305) receiving weak sewage con-

tains only one-half as much unoxidized nitrogen as the filter operating at the same rate but receiving sewage twice as strong.

Diagram No. 12.



Sewage Applied. Record of Filters Nos. 1, 2, 4, 5C, 6, 9A and 10.

Filter Numbers.	Date when Sewage was First Applied.	Actual Number of Gallons Applied to Dec. 1, 1908.	Gallons per Acre.
1,	Jan. 10, 1888,	2,251,032	450,206,400
2,	Dec. 19, 1887,	1,184,956	236,991,200
4,	Dec. 19, 1887,	752,376	150,475,200
5C,	July 20, 1905,	269,000	53,800,000
6,	Jan. 12, 1888,	1,798,594	359,718,800
9A,	Nov. 18, 1890,	1,758,219	351,643,800
10,	July 18, 1894,	593,035	118,607,000

The following tables present the average yearly analyses of all the filters so far discussed: —

Average Yearly Analyses of Effluent of Filter No. 1.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.). Sewage.	Temperature (Deg. F.). Effluent.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.
1888,	53,400	53	51	-	0.1823	.0277	4.97	0.8000	.0031	-
1889,	68,600	54	53	-	0.0639	.0283	4.64	1.4960	.0017	-
1890,	84,200	54	53	-	0.1362	.0392	5.92	1.8572	.0039	0.30
1891,	115,800	54	53	-	0.2367	.0490	7.57	1.3022	.0222	0.39
1892,	124,100	54	53	.19	0.3092	.0757	8.32	1.5237	.0212	0.54
1893,	105,900	55	51	.07	0.5652	.0965	7.21	2.1269	.0238	0.65
1894,	70,300	54	53	.06	0.4719	.0674	9.33	3.1200	.0606	0.45
1895,	67,400	58	55	.32	0.3889	.0647	11.74	2.6800	.1000	0.69
1896,	56,600	56	55	.20	0.3646	.0543	9.35	2.9800	.0618	0.43
1897,	62,100	56	55	.29	0.5502	.0697	8.36	2.7100	.0118	0.45
1898,	60,500	56	55	.24	0.3851	.0628	7.03	2.6400	.0225	0.50
1899,	54,800	56	55	.26	0.5404	.0650	6.52	2.5700	.0067	0.59
1900,	51,900	57	55	.33	0.6135	.0657	9.01	2.7400	.0020	0.64
1901,	57,200	58	55	.87	2.3591	.1199	11.09	1.8800	.0017	1.12
1902,	56,600	57	54	.47	1.9887	.0857	10.48	2.2300	.0016	0.75
1903,	72,000	56	53	.48	1.7569	.0807	11.00	2.8100	.0012	0.76
1904,	54,900	59	53	.43	1.5986	.0891	11.68	3.3400	.0045	0.70
1905,	59,600	59	52	.24	0.4690	.0522	7.98	2.8000	.0065	0.51
1906,	54,100	62	55	.24	0.5566	.0567	12.04	4.2900	.0056	0.56
1907,	50,700	61	54	.35	1.0772	.0683	10.16	4.0900	.0030	0.80
1908,	59,100	62	57	.29	0.3909	.0476	7.80	2.9800	.0008	0.55

Average Yearly Analyses of Effluent of Filter No. 2.

Year.	Quantity Applied.	Sewage.	Effluent.	Color.	Free.	Albuminoid.	Chlorine.	Nitrates.	Nitrites.	Oxygen Consumed.
1888,	28,200	53	51	-	0.1825	.0129	4.85	0.6600	.0168	-
1889,	32,000	54	53	-	0.0063	.0069	4.91	1.1000	.0045	-
1890,	39,600	54	53	-	0.0083	.0102	5.44	1.6300	.0006	0.09
1891,	50,800	54	53	-	0.3141	.0258	7.59	1.0500	.0063	0.23
1892,	24,500	54	53	.19	0.5768	.0283	8.03	1.4400	.0070	0.23
1893,	40,300	55	51	.07	0.2815	.0233	7.08	2.4100	.0569	0.19
1894,	43,900	54	53	.06	0.1069	.0173	7.92	2.8500	.0138	0.15
1895,	33,700	57	52	.09	0.5753	.0263	10.36	2.6700	.0082	0.25
1896,	37,000	56	54	.11	0.3360	.0267	9.81	3.2800	.0027	0.21
1897,	39,100	56	54	.10	0.3506	.0232	8.75	3.0600	.0079	0.22
1898,	38,300	56	54	.08	0.1693	.0204	6.05	2.3000	.0073	0.20
1899,	34,400	57	55	.13	0.4022	.0264	6.14	2.1800	.0254	0.31
1900,	33,800	57	55	.14	0.3773	.0240	9.70	3.2900	.0266	0.32
1901,	36,300	58	55	.37	1.2900	.0613	11.13	2.4100	.0067	0.63
1902,	31,200	56	53	.40	1.5521	.0518	10.61	2.6600	.0012	0.56
1903,	34,700	56	52	.30	1.3401	.0391	9.70	3.2000	.0061	0.48
1904,	32,600	59	52	.30	1.7485	.0751	11.83	2.3300	.0104	0.77
1905,	33,100	59	51	.22	0.7684	.0408	7.31	2.8400	.0104	0.41
1906,	35,000	61	54	.11	0.1988	.0263	10.51	4.4600	.0246	0.26
1907,	29,800	61	53	.34	1.2446	.0619	9.89	3.4300	.0110	0.77
1908,	29,400	63	55	.11	0.0314	.0158	7.31	3.1200	.0008	0.23

Average Yearly Analyses of Effluent of Filter No. 4.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.). Sewage.	Temperature (Deg. F.). Effluent.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.
1888,	28,700	53	51	-	0.3102	.0348	4.62	0.22	.0020	-
1889,	20,000	54	53	-	0.0104	.0122	4.29	0.64	.0002	-
1890,	33,200	54	52	-	0.0018	.0125	6.00	1.27	.0000	0.14
1891,	41,400	54	52	-	0.0581	.0153	5.62	1.45	.0008	0.17
1892,	41,800	54	53	1.62	0.5226	.0542	6.95	0.68	.0027	0.79
1893,	32,300	54	52	0.22	0.0891	.0318	6.61	1.45	.0034	0.35
1894,	20,100	55	54	0.30	0.4786	.0330	7.85	1.52	.0061	0.42
1895,	15,800	57	55	0.12	0.0853	.0190	9.41	2.06	.0020	0.19
1896,	19,000	57	54	0.12	0.2291	.0281	10.31	2.78	.0042	0.19
1897,	19,400	56	55	0.05	0.0660	.0166	7.89	2.98	.0009	0.11
1898,	19,300	56	55	0.02	0.0355	.0119	6.13	2.27	.0005	0.10
1899,	16,800	56	53	0.03	0.0897	.0142	6.27	2.04	.0068	0.18
1900,	17,800	57	56	0.04	0.0695	.0129	8.96	3.17	.0077	0.13
1901,	20,400	58	55	0.08	0.5290	.0226	9.15	2.74	.0011	0.17
1902,	19,600	56	54	0.27	1.2474	.0555	10.00	3.08	.0006	0.43
1903,	18,200	56	52	0.11	0.2796	.0169	9.34	3.10	.0001	0.21
1904,	18,000	60	52	0.13	0.2719	.0252	10.88	3.44	.0036	0.26
1905,	20,600	59	51	0.07	0.1949	.0183	6.84	3.07	.0159	0.18
1906,	19,000	61	53	0.05	0.0269	.0136	9.81	4.62	.0016	0.16
1907,	18,400	61	52	0.06	0.4951	.0237	9.49	4.16	.0169	0.36
1908,	18,700	62	54	0.07	0.0834	.0128	7.25	2.72	.0021	0.17

Average Yearly Analyses of Effluent of Filter No. 6.

Year.	Quantity Applied.	Temp. Sewage.	Temp. Effluent.	Color.	Ammonia Free.	Ammonia Albuminoid.	Chlorine.	Nitrates.	Nitrites.	Oxygen Consumed.
1888,	39,500	53	52	-	0.0905	.0130	4.71	0.71	.0020	-
1889,	41,000	54	53	-	0.0063	.0095	4.60	1.42	.0004	-
1890,	55,200	54	52	-	0.0096	.0179	5.45	1.23	.0005	0.10
1891,	61,200	55	52	-	0.1725	.0302	7.30	1.34	.0027	0.26
1892,	46,900	55	54	0.30	0.7055	.0437	8.42	1.62	.0320	0.40
1893,	35,500	54	53	0.19	0.4320	.0610	7.39	2.19	.0996	0.42
1894,	54,300	56	55	0.19	0.1780	.0473	9.80	2.96	.0962	0.43
1895,	57,600	57	53	0.27	0.7271	.0698	10.96	2.54	.0797	0.54
1896,	56,800	56	55	0.24	0.6067	.0652	10.49	2.73	.1266	0.58
1897,	60,500	56	55	0.27	0.4086	.0581	8.09	2.82	.0685	0.41
1898,	65,600	56	54	0.20	0.2213	.0406	7.06	2.73	.0158	0.35
1899,	59,400	56	53	0.22	0.3250	.0409	5.90	2.58	.0022	0.40
1900,	51,700	57	55	0.30	0.5706	.0581	8.84	2.90	.0037	0.56
1901,	57,600	58	55	0.67	1.6564	.0901	10.32	2.37	.0012	0.88
1902,	58,000	56	55	0.52	2.1817	.0808	9.86	2.21	.0085	0.68
1903,	70,200	56	53	0.46	1.5926	.0652	10.23	2.54	.0020	0.65
1904,	54,400	60	53	0.48	1.6023	.0829	11.14	3.05	.0048	0.70
1905,	56,000	59	52	0.24	0.5585	.0541	7.24	2.70	.0143	0.42
1906,	58,800	61	55	0.25	0.6947	.0607	11.73	4.25	.0150	0.55
1907,	39,400	61	54	0.76	1.3967	.1360	9.84	2.91	.0022	1.51
1908,	38,800	61	53	0.22	0.1880	.0396	7.91	3.15	.0004	0.40

Average Yearly Analyses of Effluent of Filter No. 1.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Color.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.
		Sewage.	Effluent.		Free.	Albuminoid.		Nitrates.	Nitrites.	
1888,	53,400	53	51	-	0.1823	.0277	4.97	0.8000	.0031	-
1889,	63,600	54	53	-	0.0639	.0283	4.64	1.4960	.0017	-
1890,	84,200	54	53	-	0.1362	.0392	5.92	1.3572	.0039	0.30
1891,	115,800	54	53	-	0.2367	.0490	7.57	1.3022	.0222	0.39
1892,	124,100	54	53	.19	0.3092	.0757	8.32	1.5237	.0212	0.54
1893,	105,900	55	51	.07	0.5682	.0965	7.21	2.1269	.0238	0.65
1894,	[illegible]	54	53	.06	0.4719	.0674	9.33	3.1200	.0608	0.45
1895,	[illegible]	58	55	.32	0.8889	.0847	11.74	2.6800	.1000	0.69
1896,	[illegible]	[illegible]	[illegible]	.20	0.3646	.0543	9.35	2.9800	.0618	0.43
1897,	[illegible]	[illegible]	[illegible]	.29	0.5502	.0697	8.36	2.7100	.0118	0.45
1898,	[illegible]	[illegible]	[illegible]	.44	0.3851	.0628	7.03	2.6400	.0225	0.50
1899,	[illegible]	[illegible]	[illegible]	[illegible]	0.5404	.0650	6.52	2.5700	.0037	0.59
1900,	[illegible]	[illegible]	[illegible]	[illegible]	0.6135	.0657	9.01	2.7400	.0020	0.64
1901,	[illegible]	[illegible]	[illegible]	[illegible]	2.3591	.1199	11.09	1.8800	.0017	1.12
1902,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0857	[illegible]	2.2300	.0016	0.75
1903,	72,000	[illegible]	[illegible]	[illegible]	1.7589	.0807	[illegible]	2.8100	.0012	0.76
1904,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0891	[illegible]	[illegible]	.0045	0.70
1905,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0522	[illegible]	[illegible]	.0065	0.51
1906,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0567	[illegible]	[illegible]	.0056	0.56
1907,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0030	0.80
1908,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0008	0.55

Average Yearly [illegible] Filter N[illegible]

Year.	Quantity Applied.	Temp. Sewage.	Temp. Effluent.	Color.	Ammonia Free.	Ammonia Albuminoid.	Chlorine.	Nitrates.	Nitrites.	Oxygen Consumed.
1888,	28,200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
1889,	32,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
1890,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.09
1891,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.22
1892,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.23
1893,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.19
1894,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1895,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1896,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1897,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1898,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1899,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1900,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1901,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1902,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1903,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1904,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Average Yearly Analyses of Effluent of Filter No. 4.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Color.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.
		Sewage.	Effluent.		Free.	Albuminoid.		Nitrates.	Nitrites.	
1888,	23,700	53	51	-	0.3102	.0348	4.62	0.22	.0020	-
1889,	20,000	54	53	-	0.0104	.0122	4.29	0.64	.0002	-
1890,	33,200	54	52	-	0.0018	.0125	6.00	1.27	.0000	0.14
1891,	41,400	54	52	-	0.0581	.0153	5.62	1.45	.0008	0.17
1892,	41,800	54	53	1.62	0.5226	.0542	6.95	0.68	.0027	0.79
1893,	32,300	54	52	0.22	0.0891	.0313	6.61	1.45	.0034	0.35
1894,	20,100	55	54	0.30	0.4786	.0330	7.85	1.52	.0061	0.42
1895,	15,800	57	55	0.12	0.0853	.0190	9.41	2.06	.0020	0.19
1896,	19,000	57	54	0.12	0.2291	.0281	10.31	2.78	.0042	0.19
1897,	19,400	56	55	0.05	0.0660	.0166	7.89	2.93	.0009	0.11
1898,	19,300	56	55	0.02	0.0355	.0119	6.13	2.27	.0005	0.10
1899,	16,800	56	53	0.03	0.0897	.0142	6.27	2.04	.0068	0.13
1900,	17,800	57	56	0.04	0.0695	.0129	8.96	3.17	.0077	0.13
1901,	20,400	58	55	0.08	0.5290	.0226	9.15	2.74	.0011	0.17
1902,	19,600	56	54	0.27	1.2474	.0555	10.00	3.08	.0006	0.43
1903,	18,200	56	52	0.11	0.2796	.0169	9.34	3.10	.0001	0.21
1904,	18,000	60	52	0.13	0.2719	.0252	10.88	3.44	.0036	0.26
1905,	20,600	59	51	0.07	0.1949	.0183	6.84	3.07	.0159	0.18
1906,	19,000	61	53	0.05	0.0269	.0136	9.81	4.62	.0016	0.16
1907,	18,400	61	52	0.06	0.4951	.0237	9.49	4.16	.0169	0.36
1908,	18,700	62	54	0.07	0.0334	.0128	7.25	2.72	.0021	0.17

Average Yearly Analyses of Effluent of Filter No. 6.

1888,	39,500	53	52	-	0.0905	.0130	4.71	0.71	.0020	-
1889,	41,000	54	53	-	0.0063	.0095	4.60	1.42	.0004	-
1890,	55,200	54	52	-	0.0096	.0179	5.45	1.23	.0005	0.10
1891,	61,200	55	52	-	0.1725	.0302	7.30	1.34	.0027	0.26
1892,	46,900	55	54	0.30	0.7055	.0437	8.42	1.62	.0320	0.40
1893,	85,500	54	53	0.19	0.4820	.0610	7.39	2.19	.0996	0.42
1894,	54,300	56	55	0.19	0.1780	.0473	9.80	2.96	.0962	0.43
1895,	57,600	57	53	0.27	0.7271	.0698	10.96	2.54	.0797	0.54
1896,	56,800	56	55	0.24	0.6067	.0652	10.49	2.73	.1266	0.58
1897,	60,500	56	55	0.27	0.4086	.0581	8.09	2.82	.0635	0.41
1898,	65,600	56	54	0.20	0.2213	.0406	7.06	2.73	.0158	0.35
1899,	59,400	56	53	0.22	0.3250	.0409	5.90	2.58	.0022	0.40
1900,	51,700	57	55	0.30	0.5706	.0581	8.84	2.90	.0037	0.56
1901,	57,600	58	55	0.67	1.6564	.0901	10.32	2.37	.0012	0.88
1902,	58,000	56	55	0.52	2.1817	.0808	9.38	2.21	.0085	0.68
[illegible]	70,200	56	53	0.46	1.5926	.0652	10.23	2.54	.0020	0.65
[illegible]	54,400	60	53	0.48	1.6023	.0829	11.14	3.05	.0048	0.70
[illegible]	56,000	59	52	0.24	0.5585	.0541	7.24	2.70	.0143	0.42
[illegible]	53,800	61	55	0.25	0.6947	.0607	11.73	4.25	.0150	0.55
[illegible]	39,400	61	54	0.76	1.3957	.1360	9.84	2.91	.0022	1.51
[illegible]	38,800	61	58	0.22	0.1880	.0395	7.91	3.15	.0004	0.40

Average Yearly Analyses of Effluent of Filter No. 1.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.). Sewage.	Temperature (Deg. F.). Effluent.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.
1888,	53,400	58	51	-	0.1823	.0277	4.97	0.8000	.0031	-
1889,	63,600	54	53	-	0.0639	.0283	4.64	1.4960	.0017	-
1890,	84,200	54	53	-	0.1362	.0392	5.92	1.3572	.0039	0.30
1891,	115,800	54	53	-	0.2367	.0490	7.57	1.3022	.0222	0.39
1892,	124,100	54	53	.19	0.3092	.0757	8.32	1.5237	.0212	0.54
1893,	105,900	55	51	.07	0.5652	.0965	7.21	2.1269	.0238	0.65
1894,	70,300	54	53	.06	0.4719	.0674	9.33	3.1200	.0608	0.45
1895,	67,400	58	55	.32	0.8889	.0647	11.74	2.6800	.1000	0.69
1896,	56,600	56	55	.20	0.3646	.0543	9.35	2.9800	.0618	0.43
1897,	62,100	56	55	.29	0.5502	.0697	8.36	2.7100	.0118	0.45
1898,	60,500	56	55	.24	0.3851	.0628	7.03	2.6400	.0225	0.50
1899,	54,800	56	55	.26	0.5404	.0650	6.52	2.5700	.0087	0.59
1900,	51,900	57	55	.33	0.6135	.0657	9.01	2.7400	.0020	0.64
1901,	57,200	58	55	.87	2.3591	.1199	11.09	1.8800	.0017	1.12
1902,	56,600	57	54	.47	1.9887	.0657	10.48	2.2800	.0016	0.73
1903,	72,000	56	53	.48	1.7589	.0807	11.00	2.8100	.0012	0.76
1904,	54,900	59	53	.43	1.5986	.0891	11.63	3.3400	.0045	0.70
1905,	59,600	59	52	.24	0.4690	.0522	7.93	2.8000	.0065	0.51
1906,	54,100	62	55	.24	0.5566	.0567	12.04	4.2900	.0056	0.56
1907,	50,700	61	54	.35	1.0772	.0683	10.16	4.0900	.0030	0.80
1908,	59,100	62	57	.29	0.3909	.0476	7.80	2.9800	.0008	0.55

Average Yearly Analyses of Effluent of Filter No. 2.

1888,	28,200	58	51	-	0.1825	.0129	4.85	0.6600	.0168	-
1889,	32,000	54	53	-	0.0063	.0089	4.91	1.1000	.0045	-
1890,	39,600	54	53	-	0.0083	.0102	5.44	1.6300	.0003	0.09
1891,	50,800	54	53	-	0.3141	.0258	7.59	1.0500	.0083	0.22
1892,	24,500	54	53	.19	0.5768	.0283	8.03	1.4400	.0070	0.23
1893,	40,300	55	51	.07	0.2815	.0233	7.03	2.4100	.0569	0.19
1894,	43,900	54	53	.06	0.1089	.0173	7.92	2.8500	.0133	0.15
1895,	33,700	57	52	.09	0.5753	.0263	10.36	2.6700	.0082	0.25
1896,	37,000	56	54	.11	0.3360	.0267	9.81	3.2800	.0027	0.21
1897,	39,100	56	54	.10	0.3506	.0232	8.75	3.0600	.0079	0.23
1898,	38,300	56	54	.08	0.1693	.0204	6.05	2.3000	.0073	0.30
1899,	34,400	57	55	.13	0.4022	.0264	6.14	2.1800	.0254	0.32
1900,	33,800	57	55	.14	0.3773	.0240	9.70	3.2900	.0266	0.32
1901,	36,300	58	55	.37	1.2900	.0613	11.13	2.4100	.0067	0.63
1902,	31,200	56	53	.40	1.5521	.0518	10.61	2.6800	.0012	0.56
1903,	34,700	56	52	.30	1.3401	.0391	9.70	3.2000	.0051	0.46
1904,	32,600	59	52	.30	1.7485	.0751	11.83	2.8300	.0104	0.77
1905,	33,100	59	51	.22	0.7684	.0408	7.31	2.8400	.0104	0.41
1906,	35,000	61	54	.11	0.1988	.0263	10.51	4.4600	.0246	0.36
1907,	29,800	61	53	.34	1.2446	.0619	9.89	3.4300	.0110	0.77
1908,	29,400	62	55	.11	0.0314	.0158	7.31	3.1200	.0003	0.23

Average Yearly Analyses of Effluent of Filter No. 4.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Color.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.
		Sewage.	Effluent.		Free.	Albuminoid.		Nitrates.	Nitrites.	
1888,	23,700	53	51	-	0.3102	.0348	4.62	0.22	.0020	-
1889,	20,000	54	53	-	0.0104	.0122	4.29	0.64	.0002	-
1890,	33,200	54	52	-	0.0018	.0125	6.00	1.27	.0000	0.14
1891,	41,400	54	52	-	0.0581	.0153	5.62	1.45	.0008	0.17
1892,	41,800	54	53	1.62	0.5226	.0542	6.95	0.68	.0027	0.79
1893,	32,300	54	52	0.22	0.0891	.0318	6.61	1.45	.0034	0.35
1894,	20,100	55	54	0.30	0.4786	.0330	7.85	1.52	.0061	0.42
1895,	15,800	57	55	0.12	0.0853	.0190	9.41	2.06	.0020	0.19
1896,	19,000	57	54	0.12	0.2291	.0281	10.31	2.78	.0042	0.19
1897,	19,400	56	55	0.05	0.0660	.0166	7.89	2.93	.0009	0.11
1898,	19,300	56	55	0.02	0.0355	.0119	6.13	2.27	.0005	0.10
1899,	16,800	56	53	0.03	0.0897	.0142	6.27	2.04	.0068	0.13
1900,	17,800	57	56	0.04	0.0695	.0129	8.96	3.17	.0077	0.13
1901,	20,400	58	55	0.08	0.5290	.0226	9.15	2.74	.0011	0.17
1902,	19,600	56	54	0.27	1.2474	.0555	10.00	3.08	.0006	0.43
1903,	18,200	56	52	0.11	0.2796	.0169	9.34	3.10	.0001	0.21
1904,	18,000	60	52	0.13	0.2719	.0252	10.88	3.44	.0036	0.26
1905,	20,600	59	51	0.07	0.1949	.0183	6.84	3.07	.0159	0.18
1906,	19,000	61	53	0.05	0.0269	.0136	9.81	4.62	.0016	0.16
1907,	18,400	61	52	0.06	0.4951	.0237	9.49	4.16	.0169	0.36
1908,	18,700	62	54	0.07	0.0334	.0128	7.25	2.72	.0021	0.17

Average Yearly Analyses of Effluent of Filter No. 6.

1888,	39,500	53	52	-	0.0905	.0130	4.71	0.71	.0020	-
1889,	41,000	54	53	-	0.0063	.0095	4.60	1.42	.0004	-
1890,	55,200	54	52	-	0.0096	.0179	5.45	1.23	.0005	0.10
1891,	61,200	55	52	-	0.1725	.0302	7.30	1.34	.0027	0.26
1892,	46,900	55	54	0.30	0.7055	.0437	8.42	1.62	.0320	0.40
1893,	85,500	54	53	0.19	0.4820	.0610	7.39	2.19	.0996	0.42
1894,	54,300	56	55	0.19	0.1780	.0473	9.80	2.96	.0982	0.43
1895,	57,600	57	53	0.27	0.7271	.0698	10.96	2.54	.0797	0.54
1896,	56,800	56	55	0.24	0.6067	.0652	10.49	2.73	.1266	0.58
1897,	60,500	56	55	0.27	0.4086	.0581	8.09	2.82	.0385	0.41
1898,	65,600	56	54	0.20	0.2213	.0406	7.06	2.73	.0158	0.35
1899,	59,400	56	53	0.22	0.3250	.0409	5.90	2.58	.0022	0.40
1900,	51,700	57	55	0.30	0.5706	.0581	8.84	2.90	.0037	0.56
1901,	57,600	58	55	0.67	1.6564	.0901	10.32	2.37	.0012	0.88
1902,	58,000	56	55	0.52	2.1817	.0808	9.86	2.21	.0085	0.68
1903,	70,200	56	53	0.46	1.5926	.0652	10.23	2.54	.0020	0.65
1904,	54,400	60	53	0.48	1.6023	.0829	11.14	3.05	.0048	0.70
1905,	56,000	59	52	0.24	0.5585	.0541	7.24	2.70	.0143	0.42
1906,	58,800	61	55	0.25	0.6947	.0607	11.73	4.25	.0150	0.55
1907,	39,400	61	54	0.76	1.3957	.1360	9.84	2.91	.0022	1.51
1908,	33,800	61	53	0.22	0.1880	.0395	7.91	3.15	.0004	0.40

Average Yearly Analyses of Effluent of Filter No. 9A.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Color.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.
		Sewage.	Effluent.		Free.	Albuminoid.		Nitrates.	Nitrites.	
1890,[1]	110,000	45	42	–	0.8275	.0450	5.37	0.0711	.0087	.16
1891,	95,800	54	52	–	0.5004	.0240	8.26	1.3272	.0093	.22
1892,	68,100	55	54	.27	0.6470	.0384	8.46	1.3208	.0123	.36
1893,	111,700	54	53	.26	0.7244	.0598	7.52	1.9551	.0047	.40
1894,	68,800	53	54	.21	0.5252	.0432	8.14	2.9000	.0079	.31
1895,	66,000	56	54	.26	0.9863	.0784	9.84	2.5300	.0305	.53
1896,	56,300	55	54	.24	0.6431	.0608	8.99	3.1900	.0364	.47
1897,	58,800	55	55	.31	0.8399	.1263	9.18	2.7200	.0303	.72
1898,	74,200	55	54	.25	0.3243	.0458	6.16	2.2600	.0007	.39
1899,	59,500	56	55	.30	0.5537	.0539	6.23	2.4100	.0020	.54
1900,	48,800	57	55	.29	0.6992	.0490	8.53	3.0600	.0024	.53
1901,	53,900	57	54	.75	2.5645	.1050	10.90	2.2000	.0023	.96
1902,	57,000	57	54	.41	1.8780	.0612	10.13	2.3000	.0005	.55
1903,	69,200	58	54	.44	1.3523	.0570	10.64	2.6200	.0006	.61
1904,	53,800	63	54	.35	1.0046	.0594	11.51	2.9500	.0026	.56
1905,	55,300	61	54	.25	0.4477	.0463	8.14	2.6100	.0017	.47
1906,	52,800	61	56	.25	0.5752	.0491	11.71	3.9400	.0040	.54
1907,	55,700	62	55	.34	0.8643	.0615	10.21	3.4800	.0010	.72
1908,	63,700	61	57	.29	0.3476	.0410	7.40	2.4800	.0008	.52

[1] November 18 to December 31.

Average Yearly Analyses of Effluent of Filter No. 10.[1]

1894,[2]	160,000[1]	59	62	.12	0.3379	.0230	13.99	2.8200	.0077	.20
1895,	146,700	55	53	.23	0.6572	.0459	10.72	2.4000	.0334	.36
1896,	112,800	55	54	.16	0.3209	.0451	8.96	3.0100	.0573	.35
1897,	118,000	55	55	.23	0.4449	.0553	7.98	3.0800	.0236	.39
1898,	114,400	55	54	.19	0.2762	.0428	6.94	2.6800	.0055	.33
1899,	100,000	55	55	.20	0.4315	.0458	6.55	2.5500	.0074	.41
1900,	102,000	57	54	.21	0.3273	.0457	9.05	3.2300	.0138	.49
1901,	111,200	57	54	.55	1.4227	.0790	10.53	2.6600	.0051	.71
1902,	105,600	57	53	.34	0.9124	.0543	9.74	2.6000	.0021	.48
1903,	86,800	56	54	.26	0.7239	.0358	10.63	2.7100	.0005	.41
1904,	86,000	60	54	.32	0.9328	.0514	11.84	2.7700	.0019	.48
1905,	83,600	59	53	.20	0.4346	.0401	8.01	2.2900	.0038	.40
1906,	95,600	61	55	.19	0.3894	.0399	11.60	3.3400	.0078	.43
1907,	117,600	61	55	.38	0.8666	.0691	9.69	2.0600	.0078	.80
1908,	144,400	61	56	.14	0.1316	.0251	7.94	2.3300	.0008	.30

[1] Rate for quarter of surface to which sewage is applied. [2] July 18 to December 31.

Average Yearly Analyses of Effluent of Filter No. 5.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Color.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Sewage.	Effluent.		Free.	Total Albuminoid.		Nitrates.	Nitrites.		
1888,	17,600	58	51	-	1.2937	.2281	5.27	0.02	.0002	-	818
1889,	7,200	54	54	-	3.2630	.2963	4.37	0.00	.0000	-	17
1890,	7,600	55	53	-	2.6844	.1821	5.47	0.00	.0000	2.15	130
1891,	2,800	51	50	-	2.0715	.1468	3.35	0.00	.0001	1.97	180

Average Yearly Analyses of Effluent of Filter No. 5A.

Year.	Quantity Applied.	Sewage.	Effluent.	Color.	Free.	Total Albuminoid.	Chlorine.	Nitrates.	Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1891,	64,400	54	58	-	0.3318	.0418	7.48	0.87	.0116	0.32	90,090
1892,	94,400	55	54	.88	0.8150	.0930	8.65	1.14	.0278	0.69	99,090
1893,	119,200	54	53	.40	0.5843	.1266	7.57	1.82	.0133	0.72	214,100
1894,	90,600	58	54	.32	0.6474	.0878	9.11	2.67	.0382	0.56	105,700
1895,	68,300	55	55	.37	0.9945	.1151	11.33	2.47	.0214	0.75	152,500
1896,	56,100	56	55	.30	0.9807	.1424	12.76	3.03	.0700	0.86	159,600
1897,	58,800	55	55	.31	0.8399	.1263	9.18	2.72	.0808	0.72	70,800
1898,	83,200	47	39	.38	1.3907	.1508	6.51	0.97	.1998	0.88	23,000

Average Yearly Analyses of Effluent of Filter No. 5B.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Color.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.
		Sewage.	Effluent.		Free.	Albuminoid.		Nitrates.	Nitrites.	
1898,[1]	72,800	55	55	.20	0.6771	.0591	7.11	1.71	.0398	.37
1899,	81,700	56	54	.25	0.9201	.0740	6.94	2.34	.0158	.62
1900,	109,200	58	56	.42	0.8748	.0964	9.00	2.84	.0327	.81
1901,	131,500	58	55	.57	1.6674	.0901	10.31	2.47	.0050	.83
1902,	116,900	56	55	.38	1.1610	.0789	10.23	2.91	.0014	.64
1903,	90,000	56	53	.48	1.7228	.0820	10.96	2.95	.0013	.74
1904,	72,600	60	54	.46	1.5727	.0951	11.80	3.54	.0034	.76
1905,	68,100	60	49	.40	1.1136	.0717	7.36	2.90	.0043	.68

[1] Operated ten months.

Average Yearly Analyses of Effluent of Filter No. 5C.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Color.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.
		Sewage.	Effluent.		Free.	Albuminoid.		Nitrates.	Nitrites.	
1905,	54,200	64	63	.09	.0125	.0164	8.60	2.51	.0041	.19
1906,	52,900	61	56	.15	.3577	.0361	10.71	4.82	.0024	.38
1907,	44,900	61	55	.24	.6586	.0618	12.40	5.43	.0048	.68
1908,	46,500	61	56	.33	.6015	.0643	11.93	4.03	.0025	.62

Average Yearly Analyses of Effluent of Filter No. 7.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
			Free.	Total Albuminoid.		Nitrates.	Nitrites.		
1888,	24,500	51	.1227	.0112	4.65	0.88	.0059	-	3,000
1889,	16,100	54	.0012	.0075	4.37	1.30	.0001	-	432
1890,	30,500	53	.0191	.0115	5.44	0.98	.0010	.09	341
1891,	26,700	54	.4885	.0192	6.71	1.67	.0059	.15	423
1892,	20,100	53	.0953	.0136	7.68	1.67	.0069	.14	1,831
1893,	26,600	53	.9814	.0572	6.81	1.90	.0253	.53	1,829
1894,	13,800	53	.0305	.0103	6.73	2.16	.0009	.11	57

Average Yearly Analyses of Effluent of Filter No. 305.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Appearance.		Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Applied.	Effluent.	Turbidity.	Color.	Free.	Total Albuminoid.		Nitrates.	Nitrites.		
1906,	58,800	66	65	.0	.05	.6422	.0268	13.88	3.54	.0185	.18	2,000
1907,	48,900	61	55	.1	.07	.5866	.0414	12.77	4.71	.0058	.36	1,700
1908,	55,600	62	58	.4	.15	.5505	.0488	12.90	4.10	.0049	.40	7,270

Average Yearly Analyses of Effluent of Filter No. 306.

1906,	58,200	66	65	.1	.04	.2732	.0175	8.55	2.40	.0218	.15	2,300
1907,	49,500	61	55	.0	.04	.1562	.0192	5.24	2.21	.0022	.18	750
1908,	55,600	62	57	.1	.07	.2121	.0239	6.83	2.60	.0028	.23	7,700

Summer and Winter Nitrification of Sand Filters.

When poor nitrification in the filters has occurred it has happened almost invariably during the winter months, although at times a clogged surface has caused poor summer nitrification for a short period. The

average nitrates, from May 1 to October 31, inclusive, of each year, in the effluent of each of these filters, are shown in the following table. This table shows that, during the summers of 1888 to 1892, inclusive, only one-eighth to one-third as much nitrogen appeared as nitrates, in the effluents of Filters Nos. 1, 2, 4 and 6, as during the summers of 1902, 1903, 1904, 1905, 1906 and 1907. This was due partly to weaker sewage during the earlier years of operation and partly to the poor winter nitrification during some of these latter years, which was followed by intense summer nitrification and the removal of stored nitrogenous organic matter. The average nitrates during the winter period of each year, from November 30 to April 30, show interesting results. At first the nitrates during this winter period were low in amount, owing partly to the comparatively weak sewage applied and partly to the large storage of nitrogen, but they increased with the strength of the sewage, and especially with the removal of clogged sand from Filters Nos. 1, 2, 4 and 6 in 1892 and 1893 and its replacement with clean sand. Good winter nitrification occurred between 1893 and 1900. After the winter of 1901 there were several years of poor winter nitrification, due to causes already explained. From 1904 up to the present time, however, the winter nitrification has been fully as good, and, in some instances, better than during the period from 1893 to 1900. Tables showing summer and winter nitrification of these filters follow.

Summer Nitrification, Filters Nos. 1, 2, 4, 5, 6, 9A and 10. — Table showing Average Nitrogen as Nitrates during Period of May 1 to October 31, inclusive, 1888 to 1908, inclusive.

[Parts per 100,000.]

YEAR.	Filter No. 1.	Filter No. 2.	Filter No. 4.	Filter No. 5.[1]	Filter No. 6.	Filter No. 9A.	Filter No. 10.
1888,	1.20	1.04	0.30	0.02	1.09	-	-
1889,	1.81	1.27	0.63	0.00	1.68	-	-
1890,	1.60	1.94	1.33	0.00	1.58	-	-
1891,	1.51	1.03	1.88	0.00	1.77	2.18	-
1892,	1.75	2.14	0.53	0.89 [2]	2.78	2.03	-
1893,	3.16	3.58	1.73	2.19	2.98	2.89	-
1894,	3.79	3.21	1.74	3.29	3.62	3.54	3.41
1895,	3.85	3.74	2.60	3.35	3.70	3.62	3.27
1896,	3.81	4.12	3.76	3.97	3.69	3.95	3.96
1897,	3.43	3.88	3.47	3.60	3.96	4.58	4.13
1898,	3.04	2.69	3.52	2.18 [3]	3.68	2.84	3.45
1899,	2.93	2.65	2.51	2.64	3.45	3.44	3.18
1900,	3.39	3.98	3.68	3.54	3.89	4.31	4.24
1901,	3.53	4.01	4.08	3.72	4.29	4.09	4.06
1902,	3.97	4.63	4.74	3.30	4.04	3.84	3.62
1903,	4.98	5.03	4.63	4.50	4.40	4.25	3.98
1904,	4.74	3.36	4.82	4.77	4.65	3.65	3.55
1905,	3.72	4.23	3.83	2.51 [4]	3.93	3.50	3.11
1906,	5.64	5.67	5.72	6.27	5.81	5.12	3.93
1907,	4.73	4.77	4.54	6.10	3.73	3.86	2.07
1908,	3.38	3.26	2.66	4.46	3.82	2.89	2.55

[1] Filter No. 5 started January, 1888.
[2] Filter No. 5A started Sept. 14, 1891.
[3] Filter No. 5B started March 5, 1898.
[4] Filter No. 5C started July, 1905.

Average Yearly Analyses of Effluent of Filter No. 5C.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.). Sewage.	Temperature (Deg. F.). Effluent.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.
1905,	54,200	64	63	.09	.0125	.0164	8.60	2.51	.0041	.19
1906,	52,800	61	56	.15	.3577	.0361	10.71	4.82	.0024	.38
1907,	44,900	61	55	.24	.6586	.0618	12.40	5.48	.0048	.68
1908,	46,500	61	56	.33	.6015	.0643	11.93	4.03	.0025	.62

Average Yearly Analyses of Effluent of Filter No. 7.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Ammonia. Free.	Ammonia. Total Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1888,	24,500	51	.1227	.0112	4.65	0.38	.0059	-	3,000
1889,	16,100	54	.0012	.0075	4.37	1.30	.0001	-	433
1890,	30,500	53	.0191	.0115	5.44	0.98	.0010	.09	341
1891,	26,700	54	.4885	.0192	6.71	1.67	.0059	.15	423
1892,	20,100	53	.0953	.0136	7.68	1.67	.0059	.14	1,831
1893,	26,600	53	.9814	.0572	6.81	1.90	.0253	.53	1,829
1894,	13,800	53	.0305	.0103	6.73	2.16	.0009	.11	57

Average Yearly Analyses of Effluent of Filter No. 305.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature. (Deg. F.). Applied.	Temperature. (Deg. F.). Effluent.	Appearance. Turbidity.	Appearance. Color.	Ammonia. Free.	Ammonia. Total Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1906,	58,800	66	65	.0	.05	.6422	.0268	13.88	3.54	.0185	.18	2,000
1907,	48,900	61	55	.1	.07	.5866	.0414	12.77	4.71	.0058	.36	1,700
1908,	55,600	62	58	.4	.15	.5505	.0488	12.90	4.10	.0049	.40	7,270

Average Yearly Analyses of Effluent of Filter No. 306.

1906,	58,200	66	65	.1	.04	.2732	.0175	8.55	2.49	.0218	.15	2,300
1907,	49,500	61	55	.0	.04	.1562	.0192	5.24	2.21	.0022	.18	750
1908,	55,600	62	57	.1	.07	.2121	.0239	6.83	2.60	.0028	.23	7,700

Summer and Winter Nitrification of Sand Filters.

When poor nitrification in the filters has occurred it has happened almost invariably during the winter months, although at times a clogged surface has caused poor summer nitrification for a short period. The

average nitrates, from May 1 to October 31, inclusive, of each year, in the effluent of each of these filters, are shown in the following table. This table shows that, during the summers of 1888 to 1892, inclusive, only one-eighth to one-third as much nitrogen appeared as nitrates, in the effluents of Filters Nos. 1, 2, 4 and 6, as during the summers of 1902, 1903, 1904, 1905, 1906 and 1907. This was due partly to weaker sewage during the earlier years of operation and partly to the poor winter nitrification during some of these latter years, which was followed by intense summer nitrification and the removal of stored nitrogenous organic matter. The average nitrates during the winter period of each year, from November 30 to April 30, show interesting results. At first the nitrates during this winter period were low in amount, owing partly to the comparatively weak sewage applied and partly to the large storage of nitrogen, but they increased with the strength of the sewage, and especially with the removal of clogged sand from Filters Nos. 1, 2, 4 and 6 in 1892 and 1893 and its replacement with clean sand. Good winter nitrification occurred between 1893 and 1900. After the winter of 1901 there were several years of poor winter nitrification, due to causes already explained. From 1904 up to the present time, however, the winter nitrification has been fully as good, and, in some instances, better than during the period from 1893 to 1900. Tables showing summer and winter nitrification of these filters follow.

Summer Nitrification, Filters Nos. 1, 2, 4, 5, 6, 9A and 10.—Table showing Average Nitrogen as Nitrates during Period of May 1 to October 31, inclusive, 1888 to 1908, inclusive.

[Parts per 100,000.]

YEAR.	Filter No. 1.	Filter No. 2.	Filter No. 4.	Filter No. 5.[1]	Filter No. 6.	Filter No. 9A.	Filter No. 10.
1888,	1.20	1.04	0.30	0.02	1.09	-	-
1889,	1.81	1.27	0.63	0.00	1.68	-	-
1890,	1.60	1.94	1.33	0.00	1.58	-	-
1891,	1.51	1.08	1.88	0.00	1.77	2.18	-
1892,	1.75	2.14	0.58	0.89 [2]	2.78	2.03	-
1893,	3.16	3.58	1.73	2.19	2.98	2.89	-
1894,	3.79	3.21	1.74	3.29	3.62	3.54	3.41
1895,	3.85	3.74	2.60	3.35	3.70	3.62	3.27
1896,	3.81	4.12	3.76	3.97	3.69	3.95	3.96
1897,	3.43	3.88	3.47	3.60	3.96	4.58	4.13
1898,	3.04	2.69	3.52	2.18 [3]	3.68	2.84	3.45
1899,	2.93	2.65	2.51	2.64	3.45	3.44	3.18
1900,	3.39	3.98	3.68	3.54	3.89	4.31	4.24
1901,	3.53	4.01	4.08	3.72	4.29	4.09	4.06
1902,	3.97	4.63	4.74	3.30	4.04	3.84	3.62
1903,	4.98	5.03	4.63	4.50	4.40	4.25	3.98
1904,	4.74	3.36	4.82	4.77	4.65	3.65	3.55
1905,	3.72	4.23	3.83	2.51 [4]	3.93	3.50	3.11
1906,	5.64	5.67	5.72	6.27	5.81	5.12	3.93
1907,	4.73	4.77	4.54	6.10	3.78	3.86	2.07
1908,	3.38	3.26	2.66	4.46	3.82	2.89	2.55

[1] Filter No. 5 started January, 1888.
[2] Filter No. 5A started Sept. 14, 1891.
[3] Filter No. 5B started March 5, 1898.
[4] Filter No. 5C started July, 1905.

Winter Nitrification, Filters Nos. 1, 2, 4, 5, 6, 9A and 10.—Table showing Average Nitrogen as Nitrates during Period of November 1 to April 30, inclusive, 1888 to 1908, inclusive.

[Parts per 100,000.]

Period of—	Filter No. 1.	Filter No. 2.	Filter No. 4.	Filter No. 5.[1]	Filter No. 6.	Filter No. 9A.	Filter No. 10.
1888-1889,	1.18	0.66	0.80	0.02	0.97	-	-
1889-1890,	1.15	1.16	1.26	0.00	1.24	-	-
1890-1891,	0.91	0.98	0.92	0.00	1.11	0.29	-
1891-1892,	1.14	0.72	0.77	1.22[2]	0.19	0.44	-
1892-1893,	1.00	1.12	1.01	1.28	1.22	1.19	-
1893-1894,	2.41	2.41	1.14	2.48	2.19	1.91	-
1894-1895,	1.40	1.60	1.66	1.56	1.11	0.95	1.36
1895-1896,	1.98	2.12	1.80	1.61	1.66	2.04	1.95
1896-1897,	2.24	2.41	2.33	2.08	1.83	2.52	2.09
1897-1898,	2.15	2.16	2.51	1.41	1.71	1.68	1.79
1898-1899,	2.10	1.62	1.53	1.97[3]	1.79	1.52	1.68
1899-1900,	2.28	2.08	2.16	2.10	2.00	1.57	2.42
1900-1901,	0.76	1.66	2.01	1.54	1.10	0.89	1.25
1901-1902,	0.59	0.94	1.29	1.22	0.22	0.43	1.76
1902-1903,	0.70	0.99	1.34	1.42	0.50	0.72	1.67
1903-1904,	1.80	1.67	2.34	1.90	1.20	1.84	2.00
1904-1905,	2.17	1.67	2.43	2.23	1.79	1.94	1.66
1905-1906,	2.85	3.10	2.84	3.04[4]	2.62	2.74	2.69
1906-1907,	3.48	2.35	4.40	4.89	1.99	3.06	2.24
1907-1908,	2.61	2.77	2.30	3.62	2.51	1.96	1.94

[1] Filter No. 5 started January, 1888.
[2] Filter No. 5A started September 14, 1891.
[3] Filter No. 5B started March 5, 1898.
[4] Filter No. 5C started July, 1905.

Average of Yearly Average Nitrates, 1888-1908, inclusive. Filters Nos. 1, 2, 4, 6, 9A and 10.

[Parts per 100,000.]

Year.	Nitrates.	Year.	Nitrates.
1888,	0.60	1899,	2.39
1889,	1.17	1900,	3.06
1890,	1.11	1901,	2.38
1891,	1.29	1902,	2.51
1892,	1.32	1903,	2.83
1893,	2.03	1904,	2.95
1894,	2.70	1905,	2.72
1895,	2.48	1906,	4.15
1896,	3.00	1907,	3.35
1897,	2.89	1908,	2.79
1898,	2.48		

STRATIFICATION AND THE EFFECT OF HORIZONTAL LAYERS.

In all the filters started during the earlier years of the experiment station the filtering material was put into position by throwing it into water. This method always resulted in some stratification, the amount and influence of which have probably varied widely. While it can hardly be doubted that a marked stratification has some effect upon the operation of a filter from the start, the full effect is obtained only after a period of actual use. The layer of fine sand retains minute particles, either of mineral or of organic matters, which are able to pass the ordinary sand, until it becomes clogged. The passage of air and water is thus prevented, and the action of the filter ceases.

One of the first filters to show this was Filter No. 3A, described on page 493 of the report for 1891. In this case the clogging took place in a stratified layer of fine sand a short distance below coarse sand. The next filters investigated were two water filters, Nos. 35 and 36, filled first with sand of an effective size of 0.26 millimeter and a uniformity coefficient of 6.0, then with a layer of loam, both thrown into water. The amount of water which could be made to pass these filters was smaller than expected and it was supposed that the loam layers were at fault. After removal of the loam, however, it was found that the action of the filter had been limited by stratified layers in the body of the sand. These filters had been in operation only three months when they became practically impervious.

Filter No. 9A had been in operation a little over a year, and had been filtering sewage at the rate of 103,000 gallons per acre daily, with very complete purification, when poor results began to be obtained. It was supposed at first that the difficulty was due to surface clogging; but repeated disturbing and scraping of the surface did not improve matters, and after some months of poor work a thorough investigation was made in May, 1892. This showed the presence of numerous fine stratified layers from top to bottom of the filter, and it was to these layers that the failing capacity of the filter was due. They were not horizontal, nor did any one layer cover the entire area of the filter. These layers, which of course existed during the excellent work of the first year, did not in themselves clog the filter. When they became clogged, however, by matters retained from the passing sewage they became impervious and choked the filter. A mechanical analysis of one of these layers showed an effective size of 0.05 millimeter, while the effective size of the sand as a whole was 0.17 millimeter.

The stratification in Filter No. 6 was less marked than in Filter No. 9A, and the filter operated with no apparent bad results from it for

over four years. In the spring of 1892, however, the filter did poor work, and the removal of the dirty surface sand did not materially improve its condition. Afterward the sand was spaded 6 inches deep without effect. A careful examination showed stratification 8 to 10 inches below the surface. When this was broken by digging up the sand to a depth of 18 inches, the filter did good work again.

Similar conditions were found in Filter No. 4, but in this case the clogging was at the junction of the coarse and fine sands in the trenches, and not at the stratified layers, as in the other filters. In this case sewage was applied to a trench filled with coarse sand dug in the extremely fine sand of the filter. This arrangement worked satisfactorily for three years, at the end of which time the filter became clogged at the top of the fine sand at its junction with the coarse sand.

In all the above cases the direct cause of trouble was the placing of a coarser above a finer sand, but such a combination is not always followed by bad results. Indeed, it seems almost impossible to formulate any general rules in regard to the matter. It can be said, however, that in general such a filter is more or less difficult to operate, and that the difficulty increases with the coarseness of the upper and with the fineness of the lower sand, and that, probably, clogging is much more rapid near the surface than at a considerable depth.

An entirely different effect of the combination of different sands is obtained when a fine sand is placed above a coarser one. The best example of this condition is furnished by Filter No. 5A. This filter at first contained a fine screened gravel (effective size 1.40 millimeters), which was too coarse to give the best purification, but still allowed fair chemical purification with single doses of 1½ per cent. of the volume of the filter. Difficulty was experienced in obtaining an even distribution of sewage over this coarse material, so that on March 29, 1892, the upper 3 inches of gravel were removed and replaced by 1 inch of coarse sand, effective size 0.32 millimeter, 1 inch of medium sand, effective size 0.19 millimeter, and 1 inch of coarse sand, effective size 0.32 millimeter. The distribution was improved, but a choking took place on the surface of the second inch of fine sand.

It was shown in the twenty-third annual report (1891), page 432, that fine sands hold their pores full of water by capillarity for definite distances above their drainage levels, the distances depending upon the fineness of the sand. If a considerable layer of fine sand is underdrained, and sewage is put upon the top of it, the weight of the column of water in the pores of the sand and the cohesion of the water will draw the sewage down into the sand, until a point is reached at which the capillary attraction is able to hold the weight of the water in the remaining

saturated layer. The upper part of the sand is thus comparatively dry, that at the bottom extremely wet. If, however, the fine sand is supported by a coarser sand, the downward attraction is not so strong, owing to the smaller amount of cohesion of the water in the larger, partially filled pores. If, furthermore, there is much difference in the sizes of the pores of the two sands, the coarse sand will not draw the water out of the fine sand, but the bottom of the latter will remain saturated with water, although thoroughly underdrained by the coarse sand. In Filter No. 5A, with the above-mentioned covering of fine sand, the inch layer of 0.19 millimeter sand always remained saturated with water. Sewage passed it freely, but the saturated layer acted as a water seal, and prevented the passage of air. The fine sand retained many of the solid impurities of the sewage, and, since it was always saturated with water, there was no opportunity for aeration and oxidation, so that it rapidly became clogged, and after six weeks the full quantity of sewage could not be filtered.

There was reason to believe, however, that the cause of failure was at the junction of the coarse sand above the fine sand, and not at the lower junction of fine sand over coarse sand. It was determined, therefore, to repeat the experiment in such a way as to eliminate the uncertainty. On June 2 the upper 2 inches of sand were removed and replaced with clean 0.19 millimeter sand, so that nowhere in the filter was a coarse placed over a finer sand, but always a fine sand over a coarse variety. The layer of 0.19 millimeter sand being 2 inches thick, and its saturated layer only 1 inch thick, the upper inch of surface sand had an opportunity to become to some extent dry, and was therefore less likely to clog than under the earlier arrangement. The results during the following month were the best ever obtained from that filter with corresponding doses of sewage, although they did not even then equal those obtained from Filter No. 9A, which was filled with 5 feet in depth of sand of the same size as the surface sand of Filter No. 5A, and received sewage at a slightly greater average rate.

The fine sand above the coarse acted as a water seal, but could resist a pressure of only 1 inch of water, and with changes in barometer or temperature some air must have been forced through. There must have been also some ventilation through the underdrains.

We thus found that with a coarse material above a fine one in the same filter there is trouble from clogging of the surface of the fine material below the coarse; and this is far worse than surface clogging, for the latter can be completely remedied by disturbing the surface or by scraping. We found also that a fine sand supported by a coarse sand will keep its lower layer saturated, and act as a water seal, allowing the pass-

age of water but not of air, and may in this way prevent the necessary circulation of air, and reduce the action of the filter to a mere straining. Thus different materials, which by themselves may be suitable for the purification of sewage by intermittent filtration, may be so combined in a filter that oxidation is rendered imperfect or impossible.

Depth of Sand as affecting Purification in Sand Filters.—Physical Characteristics of Various Sands.

The question as to the depth of filtering material necessary to produce satisfactory and well-purified effluents by sand filtration has been given much attention at the station. The subject presents a number of practical points, such as the depth at which underdrains must be laid; the necessity in some cases of constructing filter beds by the removal of sand from one place to another rather than by the removal of surface loam from sandy areas, etc. All of the filters thus far discussed have contained 5 feet in depth of sand, with the exception of Filter No. 6, which is 3 feet 8 inches in depth.

The special report for 1890 showed that the physical characteristics of the sand used had considerable influence upon filtration. The sands at the experiment station have varied from coarse sand, with an effective size of 0.48 millimeter, as used in Filter No. 1, to the fine river silt, with an effective size of 0.04 millimeter, as used in Filter No. 4. The following figures relating to open space in sand filters and the volume of water held by filters 5 feet deep were given also in the special report for 1890. The sand of Filter No. 1 when packed closely has an open space equal to 36 per cent. of the whole volume of closely packed sand. When such a filter as No. 1 has had this open space filled with water, and then all the water that will flow away given time to flow, this body of sand, 5 feet in depth, thoroughly underdrained, holds one-third of its open space filled with water, leaving two-thirds filled with air. With the sand of Filter No. 2, of an effective size of 0.08 millimeter, the open space, when the sand is packed in the same manner, is 40 per cent. of the total volume, but with this finer sand, the figures in regard to air and water capacity, after the sand has been thoroughly saturated with water and then drained, are reversed; that is to say, fully two-thirds of the open space between the sand grains of the drained filter is then filled with water and only one-third with air. The lower foot of the 5-foot filters of this sand, though entirely underdrained, remains completely saturated with water, the second foot about three-fourths saturated, and the third foot about one-half saturated, while through the upper 2 feet sewage passes slowly. Filter No. 4, constructed of fine river silt with an effective size of 0.04 millimeter, has about 42 per cent. of open space, and holds

even more water when drained than does Filter No. 2, and of course has less available air space. As a result of these varying water and air capacities, when sewage is applied to Filter No. 1, it meets much more air than when applied to filters constructed like Nos. 2 and 4. When a filter like No. 1 is operated at a rate of 60,000 gallons per acre daily, it takes the sewage applied one day several days to reach the underdrains, and it reaches them only when it has pushed before it the sewage applied during the three previous days. With Filters Nos. 2 and 4, operated at a rate of 40,000 gallons per acre daily, the sewage applied one day takes from ten to fourteen days to reach the underdrains, pushing before it the sewage applied during this period. It follows, of course, as shown in the report for 1891, that, inasmuch as sand as fine as that of Filters Nos. 2 and 4 will hold itself saturated with water, even when completely underdrained, to a depth of 2 or 3 feet above these underdrains, shallow filters of this material cannot be used with satisfactory results; that is to say, insufficient air is present for bacterial oxidation and the sewage is simply strained, and otherwise unchanged. During the early part of 1890, several filters, 2½ feet in depth, with sand of an effective size of 0.48 and 0.17 millimeter, were put into operation, and known as Nos. 27, 28, 30 and 31. Filters Nos. 27 and 30 were constructed of sand with an effective size of 0.48 millimeter, and Filters Nos. 28 and 31 of sand with an effective size of 0.17 millimeter. To these were added Filters Nos. 26 and 29, constructed to the same depth of gravel stones. Concentrated sewage was applied to some of these filters during a portion of their period of operation, still tables below show that these filters, operated at a lower rate than filters twice as deep, produced fair purification, and were continued in operation for a number of years. It was stated in the report for 1891, in speaking of these filters, that, to a certain extent, at least, their capacity to purify sewage was directly proportional to their depth. Only the lower inch or two of the sand remained saturated, hence conditions for purification were favorable.

In 1900, two filters, namely, Nos. 140 and 141, were put into operation. These filters were constructed of medium sand with an effective size of 0.11 millimeter, Filter No. 140 being 2 feet in depth and Filter No. 141, 3 feet. These filters were operated at a rate of 50,000 gallons per acre daily. Nitrification started almost immediately and the effluent of each was of a satisfactory quality. During 1901, however, Filter No. 140 gave a considerably less satisfactory effluent than during the previous year. The effluent of Filter No. 141, 3 feet in depth, contained considerably less organic matter than that of the shallower filter, but the amount in the effluent of the shallower filter was not large. At the end

of August, 1900, the filter 3 feet in depth was put out of operation, and in its place was started a filter containing 2 feet in depth of sand of an effective size of 0.24 millimeter, that is, much coarser than in Filter No. 140 of the same depth. This filter, No. 141A, was continued in operation until the end of 1901, at the same rate as Filter No. 140, approximately 50,000 gallons per acre daily. While nitrification in this filter was active, still it was evident from the results obtained that, with this coarse sand and shallow depth, the passage of sewage was too rapid to admit of thorough oxidation, and the effluent of this filter contained considerably more unoxidized organic matter than did the effluent of Filter No. 140. Its bacterial efficiency was also much lower. In 1906 a comparison was begun between filters constructed of sand with an effective size of 0.25 millimeter, 5 and 10 feet in depth, respectively. These filters, Nos. 313 and 316, were operated at a rate of nearly 100,000 gallons per acre daily and the average analyses of their effluents up to the end of 1908 showed that with this grade of sand somewhat better work was done by the deeper filter. This difference, as determined by the actual amount of organic matter in the effluent, appears large, but when estimated upon comparative removal of organic matter, the percentage of purification is but slightly different. Adding together the free and albuminoid ammonia of these filters, we find the amount in the effluent of the 5-foot filter practically twice as great as in that of the 10-foot filter, but the average purification, as shown by per cent. of organic matter removed from the sewage, was 94 and 97 per cent., respectively. The effluent of each filter contained over 4 parts of nitrates, namely, 4.40 and 4.42 parts, respectively, the larger amount being found in the effluent of the deeper filter. The effluent of this deeper filter was only slightly more efficient bacterially than that of the shallower filter. Taking all things into consideration, the results have shown that while little or no purification can be expected from shallow filters constructed of sand as fine as that of Filters Nos. 2 and 4, yet, with coarser sands, good nitrification will occur in filters not over 2 feet in depth; that the rates must be lower than with deeper filters, and that the unoxidized or partially oxidized organic matter in the effluents of these shallow filters will be large compared with that in the deeper ones. Still, when the organic matter in the applied sewage is considered, good percentage removal of such organic matter is shown. The operation of the filter 10 feet in depth has shown also that increased efficiency is obtained with the greater depth but not enough to be of any considerable importance.

In a general way it can be said that the greater the depth of a sand filter, other things being equal, the greater the degree of purity of its effluent; that with coarse sands, a depth of 4 or 5 feet is desirable,

owing to the greater rate that can be maintained with good purification; that with such sands a filter of half this depth can be operated with good results if a lower rate is maintained; that with sands as fine as those of Filters Nos. 2 and 4, it is necessary, on account of their degree of capillarity, to have a depth sufficient to give an upper unsaturated sand layer in order that air may be introduced. This being provided for, such a filter will give an effluent of greater purity than the coarser sand filter, but is operated with greater difficulty and requires a much lower rate. Sand slightly coarser than that of Filters Nos. 2 and 4, as instanced by Filters Nos. 140, 141 and 9A, gives, with similar depths, results resembling more the coarser than the finer sands. Depth for depth, they can be operated more nearly as filters of sand as coarse as that of Filters Nos. 1 and 6, rather than as fine as that of Filters Nos. 2 and 4.

Average Analyses of Effluents of Filters Nos. 27, 28, 30, 31, 26, 29, 140, 141, 141A, 313 and 316.

Filter No. 27 (2½ Feet deep; Effective Size of Sand 0.48 Millimeter).

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
	Free.	Albuminoid.		Nitrates.	Nitrites.		
45,600	.3119	.0548	7.39	1.65	.0063	.33	25,400
Filter No. 28 (2½ Feet deep; Effective Size of Sand 0.17 Millimeter).							
46,700	.2813	.0395	7.58	1.81	.0048	.32	18,700
Filter No. 30 (2½ Feet deep; Effective Size of Sand 0.48 Millimeter).							
55,100	.0986	.0408	7.68	2.56	.0059	.28	22,500
Filter No. 31 (2½ Feet deep; Effective Size of Sand 0.17 Millimeter).							
58,800	.1036	.0259	7.31	2.56	.0064	.23	8,000
Filter No. 26 (2½ Feet deep; Gravel Stones).							
21,200	.0852	.1763	7.65	2.30	.0590	.87	59,600
Filter No. 29 (2½ Feet deep; Gravel Stones).							
25,300	.0647	.0789	7.25	2.03	.0088	.46	34,500

Average Analyses of Effluents, etc. — Concluded.

Filter No. 140 (2 Feet deep; Effective Size of Sand 0.11 Millimeter).

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
51,300	.5373	.0280	9.48	2.54	.0066	.29	1,521
Filter No. 141 (3 Feet deep; Effective Size of Sand 0.11 Millimeter).							
50,000	.0689	.0103	10.29	2.25	.0098	.10	152
Filter No. 141A (2 Feet deep; Effective Size of Sand 0.24 Millimeter).							
45,900	.8500	.0497	10.17	2.28	.0088	.40	11,350
Filter No. 313 (5 Feet deep; Effective Size of Sand 0.25 Millimeter).							
98,600	.7372	.0405	15.48	4.40	.0208	.35	9,600
Filter No. 316 (10 Feet deep; Effective Size of Sand 0.25 Millimeter).							
99,600	.3381	.0218	13.66	4.42	.0096	.21	7,900

With Equal Depths, Rate of Filtration of Sand Filters depends upon Grade of Sand, Strength of Sewage and Age of Filter.

In November, 1889, one of the first experiments was made to show the rate at which sewage would flow through Filter No. 1 when operated at a rate of 100,000 gallons per acre daily. First water was applied to the filter for three days in each week from November 28 to December 7. After this, sewage was again applied and the increase of chlorine in the effluent noted to show how rapidly the foremost particles of sewage flowed through the sand when applied in considerable quantity. The sewage applied contained 2.8 parts of chlorine per 100,000. Five hundred gallons of this sewage were applied and in forty-eight minutes the flow at the outlet showed an increase, and this increase continued for one hour and seven minutes. In this time the rate of flow from this filter, $\frac{1}{200}$ of an acre in area, increased from $\frac{1}{40}$ of a gallon to 15 gallons per minute. The chlorine increased at the same time from 0.75 part per 100,000 to 0.94 part per 100,000. The change in chlorine in

the effluent showed that the first particles of sewage reached the outlet in about fifty minutes; that is to say, although 1,000 gallons of water were held in the interstices of the sand, the first particles of the sewage, moving rapidly through the larger interstices and pushing before them but little of the contained water, reached the outlet about three-quarters of an hour after the application of 500 gallons of sewage. The maximum amount of the sewage together with the minimum amount of contained water did not, however, reach the outlet until the third day after application of the sewage.

A like experiment with Filter No. 2 showed that under similar conditions it required a week for the first particles of sewage to reach the outlet pipe, and, as stated earlier in this report, with the fine clay hardpan originally in Tank No. 9, one year elapsed before the sewage passed through 5 feet of this material and reached the filter outlet. These differences in mechanical composition of filtering materials control the rate that can be followed with satisfactory results, and also the method of operation as regards the volume of sewage applied at one time and the time that must elapse between successive applications of sewage. With the coarser materials the amount of sewage which can be applied at one time is limited by the small retention capacity of the sand. If too large a volume is added a portion will pass through the filter in too short a period for good purification.[1] Such a filter may receive comparatively small but frequent applications of sewage, the small volume being made necessary by the small water retention capacity of the sand, and the frequent applications being allowed on account of the large portion of the open space filled with air, and hence the capacity of the filter to purify sewage with fair rapidity. With the fine materials, the volume of sewage applied at one time can be much greater, owing to the high retention capacity of the sand for water, but the frequency of application must be considerably less, owing to this same retention capacity, and the comparatively small amount of air that remains in the filter for bacterial oxidation. With a filter such as No. 1, daily or semidaily applications of comparatively small volumes is the best method, but with filters of such materials as Filters Nos. 2 and 4, less frequent applications should be made if maximum purification is to be achieved. The volume of sewage which can be applied at any one time, however, has no definite relation to the volume of sewage which can be purified within a given time. The coarser sands, in Filters Nos. 1, 6 and 9A, can, even when first put in use, purify a considerably larger volume of sewage daily, although the average application be small, than sands such

[1] In discussion of filter results "good purification" may have a very different meaning when applied to filters of differing types.

as those in Filters Nos. 2 and 4, although the average volume applied at one time may be large.

Some of the conclusions reached in the earlier years of operation of these filters have been much modified, however. This modification has been due to the fact that the accumulation of organic matter in the upper portions of filters of coarse material has placed them in many respects within the class of filters of fine material as regards the volume of sewage that can be applied at any one time. Too great an accumulation may, furthermore, increase capillarity and cause conditions similar to stratification, or the overlying of a coarse material by a finer one, and, in this way, decrease both the quantitative and qualitative efficiency of the filter. The filters of coarse material strain better and improve up to a certain point with this accumulation of organic matter, but materials as fine as those in Filters Nos. 2 and 4 do not increase in efficiency through the accumulation of organic matter. It has been found from time to time, moreover, that frost in the upper portions of coarse filters by closing to a certain extent the pores, causes these filters to have temporarily the same mechanical action as filters of fine material.

As the investigations continued, similar problems arose as regards methods of application of sewage to some of the disposal areas in the State. At many of these areas it was found that faulty methods of operation were at times followed, whereby day after day volumes of sewage were added to certain beds several times greater than the retention capacity of the sands of these beds would justify where this sand was coarse, and, in other instances, greater than was necessary to fill the entire open space in the sand of these beds when they were constructed of fine sand. It was at times, moreover, a mooted question whether, in some instances, it would not be of value to flood frequently, that is, several times a day, some of these areas, irrespective of the grade of sand of which they were constructed.

In 1906 studies upon this point were begun with a series of filters of equal depths, each containing sand of an effective size of 0.25 millimeter, and these filters were continued in operation for approximately two years. One filter was operated at a rate of 50,000 gallons per acre daily; one at a rate of 100,000 gallons per acre daily and two at a rate of 150,000 gallons per acre daily. To one of the filters, operated at the rate of 150,000 gallons per acre daily, the sewage was applied in one dose each day, and to the other, part of the time in six applications two hours apart, and part of the time in eight applications. With this grade of sand, Filters Nos. 312 and 313, receiving sewage at the rate of 50,000 and 100,000 gallons per acre daily, respectively, produced very similar purification results although, of course, a slightly

better effluent was given by the filter receiving the smaller volume of sewage. Of the two filters operated at 150,000 gallons per acre daily, Nos. 314 and 315, better results were given by the filter to which the sewage was applied in one dose daily, and the filter was operated much more easily, less disturbance of the surface layers and also fewer periods of rest being necessary. These results, of course, emphasize the fact that too frequent flooding of a filter constructed of sand even as coarse as in this case causes the open space in the upper layers of sand to remain saturated or nearly so with water, to the exclusion of air. Average analyses of the effluents of these filters follow.

Average Analyses of Effluents of Filters Nos. 312, 313, 314 and 315.

Filter No. 312.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).		Appearance.		Ammonia.			Nitrogen as —			
	Sewage.	Effluent.	Turbidity.	Color.	Free.	Albuminoid.	Chlorine.	Nitrates.	Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
49,700	53	56	0.0	.07	.1350	.0233	13.75	5.12	.0017	.25	960
Filter No. 313.											
98,690	55	61	0.1	.15	.7372	.0405	15.48	4.40	.0208	.85	9,600
Filter No. 314.											
144,900	53	58	0.2	.28	.8346	.0567	13.84	4.69	.0435	.57	2,282
Filter No. 315.											
138,600	53	58	0.1	.25	.8816	.0607	14.20	4.57	.0072	.60	3,275

Load of Organic Matter that can be cared for by a Sand Filter.

There is a certain fixed amount of organic matter which a sand filter can receive year after year with a minimum amount of storage, this amount varying, however, with the relative proportion of matter in solution to that in suspension in the applied sewage. This unit amount of organic matter bears little relation to the volume of sewage containing it, but varies somewhat according to the class of sewage, whether domestic or a mixture of domestic and industrial sewage; it varies also with the grade of sand. During the first two years of operation of

Filters Nos. 1, 2, 4 and 6, the rate was low when the quality of the sewage applied is considered. Not only was the rate increased during the next few years, but the strength of the sewage increased also, so that an excessive load of organic matter was applied yearly to some of these filters. During 1891, 1892 and 1893 the amount of unoxidized and partially oxidized nitrogen applied to Filter No. 1 was from two to four times as great as during 1888 and 1889. With filters Nos. 2 and 4, the increase while not so great was more than doubled, and although the percentage removal of unoxidized nitrogen decreased but slightly still the effluents of these filters were of a poorer quality. After this, the rates of these filters were changed or reduced from time to time in order that they might not be so overloaded with organic matter as to cause poor purification. Reference to the diagram on page 311 shows the amount of nitrogen as applied, as found in effluent, as stored in or as lost from Filter No. 1 during its first twenty-one years of operation. The decreased amount of nitrogen applied each year from 1894 to the end of 1908, as compared with that applied during 1891, 1892 and 1893, is also clearly shown. During 1908 the amount applied was only slightly greater than during 1889, less than half the amount applied in 1892 and only slightly more than half the amount applied in 1893. This fact is shown also by the table of units of unoxidized nitrogen applied in different years, given on page 317. A similar diagram for Filter No. 6 shows that, while the amount of nitrogen applied has varied considerably, it has been in most of the years since 1894 considerably less than during that year, and the same is true of Filter No. 9A. In most of the years since 1891, 1892 and 1893, moreover, there has been comparatively little storage of organic matter, because the amount of applied nitrogen has been kept within reasonable limits, that is, within the amount that the filter can usually care for. A marked deterioration in the quality of the effluents occurred when the amount of applied nitrogen was abnormally high, during the early 90's, but these effluents improved in later years, until 1901, 1902, 1903 and 1904, when, as described above, the upper portions of the filters became badly clogged. (See page 275.) Following the improvement in the method of treatment given the filters at this time, the effluents improved again.

That the volume of sewage that can be purified by intermittent sand filtration is, within reasonable limits of strength of sewage, determined rather by the amount of organic matter present than by the volume of sewage in which this organic matter is held, was clearly shown by Filters Nos. 128, 129 and 130, started in August, 1899, and continued in operation until the end of June, 1901. Each of these filters contained 5 feet in depth of sand of an effective size of 0.26 millimeter. To Filter No.

128 station sewage was applied; to Filter No. 129, the same volume plus an equal volume of river water; and to Filter No. 130, an equal volume of sewage plus two volumes of river water, making the respective rates of these filters 92,000, 184,200 and 276,700 gallons per acre daily. That is, each filter received approximately the same amount of organic matter but in widely varying volumes of water. Each filter produced a good effluent containing a small amount of unoxidized organic matter and nitrates proportional in amount to the nitrogen and the volume of water in which this applied nitrogen was contained. Each filter was operated without difficulty, and the filter receiving the weak sewage had its surface covered after each application but little, if any, longer than that receiving the strong sewage, even though the latter contained only one-third as much liquid. A table showing the average analyses of the effluents of these filters follows: —

Average Analyses of Effluents of Filters Nos. 128, 129 and 130.

Filter No. 128.

[Parts per 100,000.]

Quantity Applied. Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.). Sewage.	Temperature (Deg. F.). Effluent.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
92,000	56	57	.14	.1399	.0266	8.77	3.57	.0252	.27	7,600

Filter No. 129.

184,200	54	55	.15	.0307	.0237	8.99	1.70	.0035	.26	13,700

Filter No. 130.

276,700	53	55	.21	.0216	.0257	8.05	1.02	.0054	.30	19,500

Sand Filter Rates can be increased only in Proportion to the Amount of Organic Matter removed by Sedimentation, Chemical Precipitation, etc.

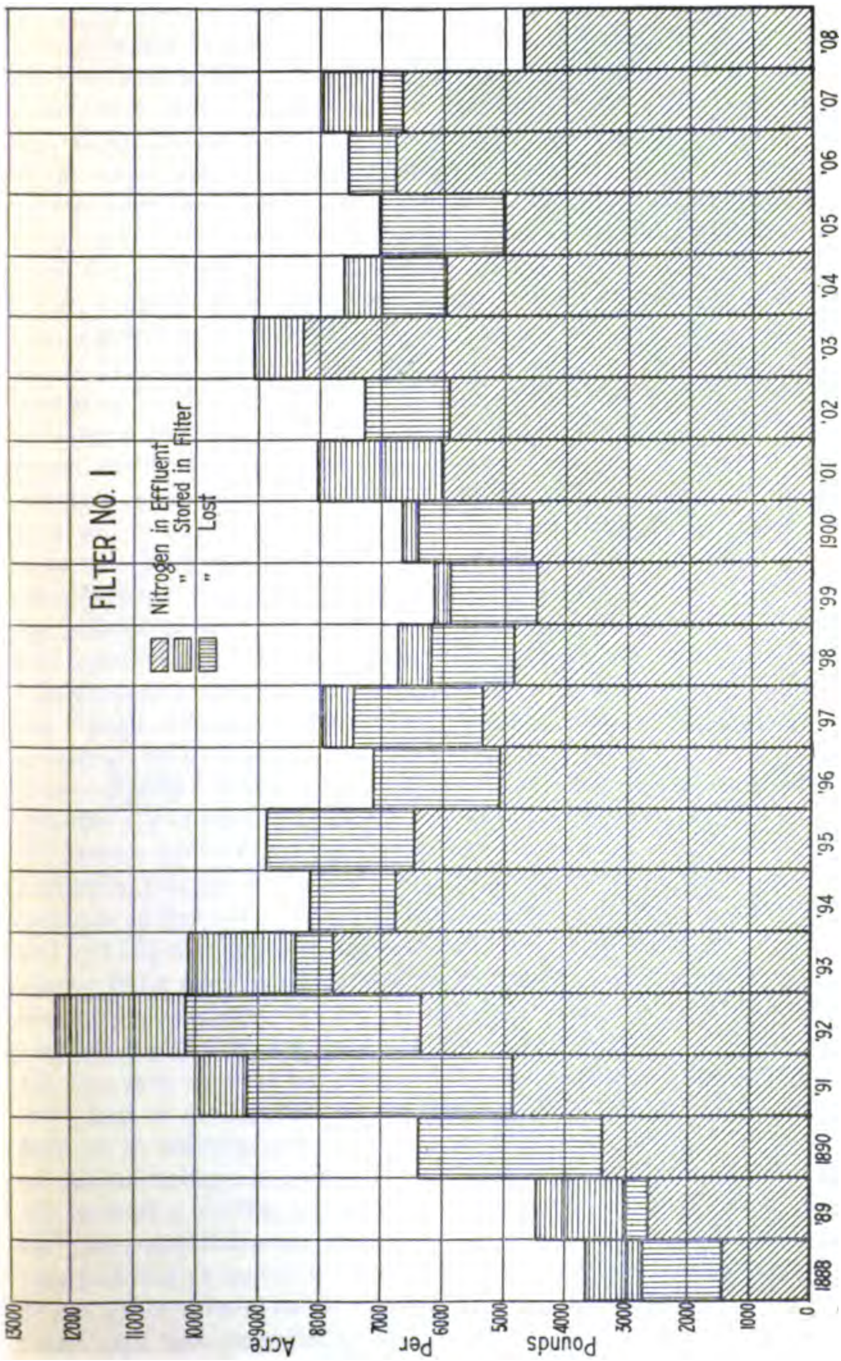
In subsequent portions of this report discussions will be given concerning purification by sand filtration of sewage clarified by chemical precipitation, straining and other treatment. Under these conditions the filters could be operated at rates much higher than those receiving untreated sewage. Indeed, all were operated at rates so high that the load of organic matter applied could not be cared for by bacterial oxidation and sand removal frequently became necessary. The object was a

high rate with a satisfactory effluent. It was expected that removal, renewal or washing of clogged sand would be necessary. It is true that a large portion of the load applied to these filters was organic matter in solution, and hence presumably more easily and quickly disintegrated and oxidized than the undissolved organic matter in untreated sewage. The tables on pages 317–322, inclusive, show that the average yearly "units" of nitrogen applied to Filter No. 1 were 283; to Filter No. 6, 239; to Filter No. 9A, 287, these filters receiving untreated sewage; but to Filter No. 14A, receiving strained sewage, the average yearly units were 1,177; to Filter No. 19, receiving chemically clarified sewage, 969; and to Filter No. 100, receiving septic sewage, 948, these great amounts being due to the greatly increased rates of application. The depths of sand that had to be removed from these filters in order to keep them in satisfactory operation are discussed on pages 333 and 334, and when compared with similar figures from Filters Nos. 1 to 10, inclusive, it is clear that these greater rates are possible only through more frequent sand removal. Scientifically the rates can be increased only in proportion to the degree of removal of suspended matter in the sewage. Generally the rates attempted in filtering clarified sewage are, as in the case of the filters just mentioned, greater than the amount of clarification justifies.

Application and Storage of Nitrogen — Nitrification.

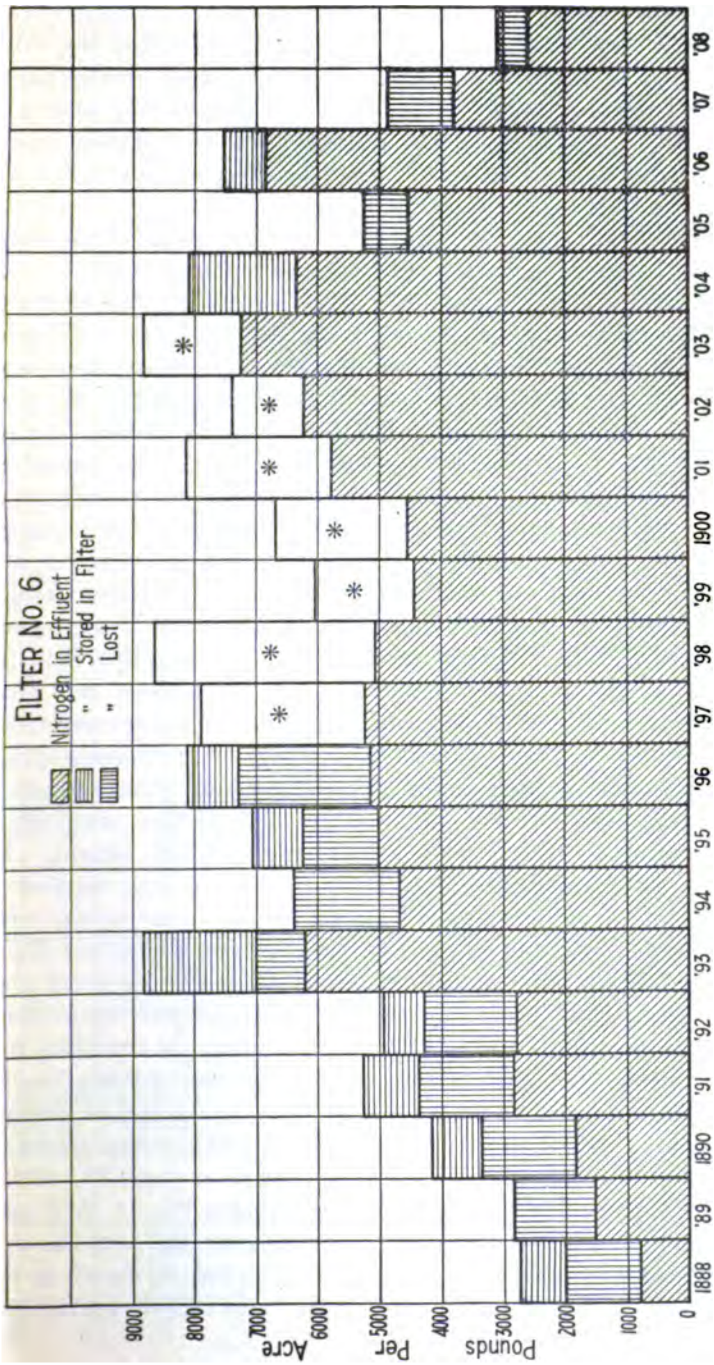
It was noticed during the first year of operation of the sand filters that a certain proportion of the nitrogenous matter in the applied sewage was stored within the filters. It was noticed also, as shown by analyses of the sand, that after nitrification began to be active, some of this stored nitrogen was removed. For instance, Filter No. 1 stored in its first year of operation 26 per cent. of the nitrogen applied; in the second year, 8 per cent.; or during both years 16 per cent. of the nitrogen applied during these two years; and 26 per cent. of this stored nitrogen was removed during the second year. The analyses showed also that a certain percentage of the nitrogen was unaccounted for, that is, was found neither in the effluent nor stored in the filter, this nitrogen amounting in two years to 30 per cent. of that applied; that the stored nitrogen increased rapidly near the surface of the filter, and that during times of good nitrification it decreased quite rapidly in the portions of the filter some distance below the surface. Three-fourths of all the nitrogen stored in the lower 4 feet of some of the filters was removed by nitrification or by escape into the air during the second year of operation. Notwithstanding this removal during times of good nitrification, the amount actually stored increased year by year, as shown by results

Diagram No. 13.



published in the different reports, and in the report for 1891 the statement was made that "a small percentage of the more stable organic matters of the sewage resist the oxidizing action of the filter and accumulate in its upper layers." It was stated also that "this can be remedied temporarily by turning the surface under, but it does not seem probable that the continued inversion of the upper layers will allow the indefinite use of the same material while still maintaining the application of the maximum quantity of sewage. . . . It is quite possible that the removed sand, when taken entirely away from the filter, will in time so far regain its original properties as to again allow its advantageous use as a filtering material." This storage of nitrogen and other organic matter increased, however, until in 1892 and 1893 it was considered necessary to remove a considerable depth of sand from several of the filters, as noted in a previous chapter. Since that last removal in 1893, however, sand removal has been unnecessary. All the filters, nevertheless, have been kept in constant operation and, generally speaking, satisfactory purification has resulted. To accomplish this it has been necessary, among other things, to make the rate of operation such as to cause but a small amount of storage from year to year. The stable organic matters, therefore, have increased but slowly. Better care of the upper foot of material during these latter years and better winter care have aided in maintaining continuous operation. Diagrams are presented with this report showing the amount of nitrogen in pounds applied per acre to Filters Nos. 1, 6 and 9A during each year of their operation. (See Diagrams Nos. 1–3.) These diagrams show also the amount stored, the amount lost or unaccounted for and the amount found in the effluents. On the diagrams (see page 311, etc.) the total height of the column for each year represents the total nitrogen in the sewage applied, expressed in pounds *per acre*. (See Diagrams Nos. 13–15.) We find in studying Filter No. 1 on the diagram that the amount of nitrogen applied to this filter per year, expressed in pounds per acre, increased from 3,700 pounds in 1888 to 12,200 pounds in 1892. As the rates of operation were lowered following this, the average amount applied was less, and during the past fourteen years has been about 7,500 pounds per acre per year and the lowest amount in any of these years was in 1908. Even in that year, however, the amount applied was greater than during either of the first two years of operation of the filter. The same generalization can be made in regard to the other filters, although the difference between the maximum and minimum amounts applied in these different years has been less than in the case of Filter No. 1. Looking at the diagrams further, especially Nos. 4–8, it will be noticed that in some of the recent years there has been little or no storage of nitrogen, and that nitro-

Diagram No. 14.

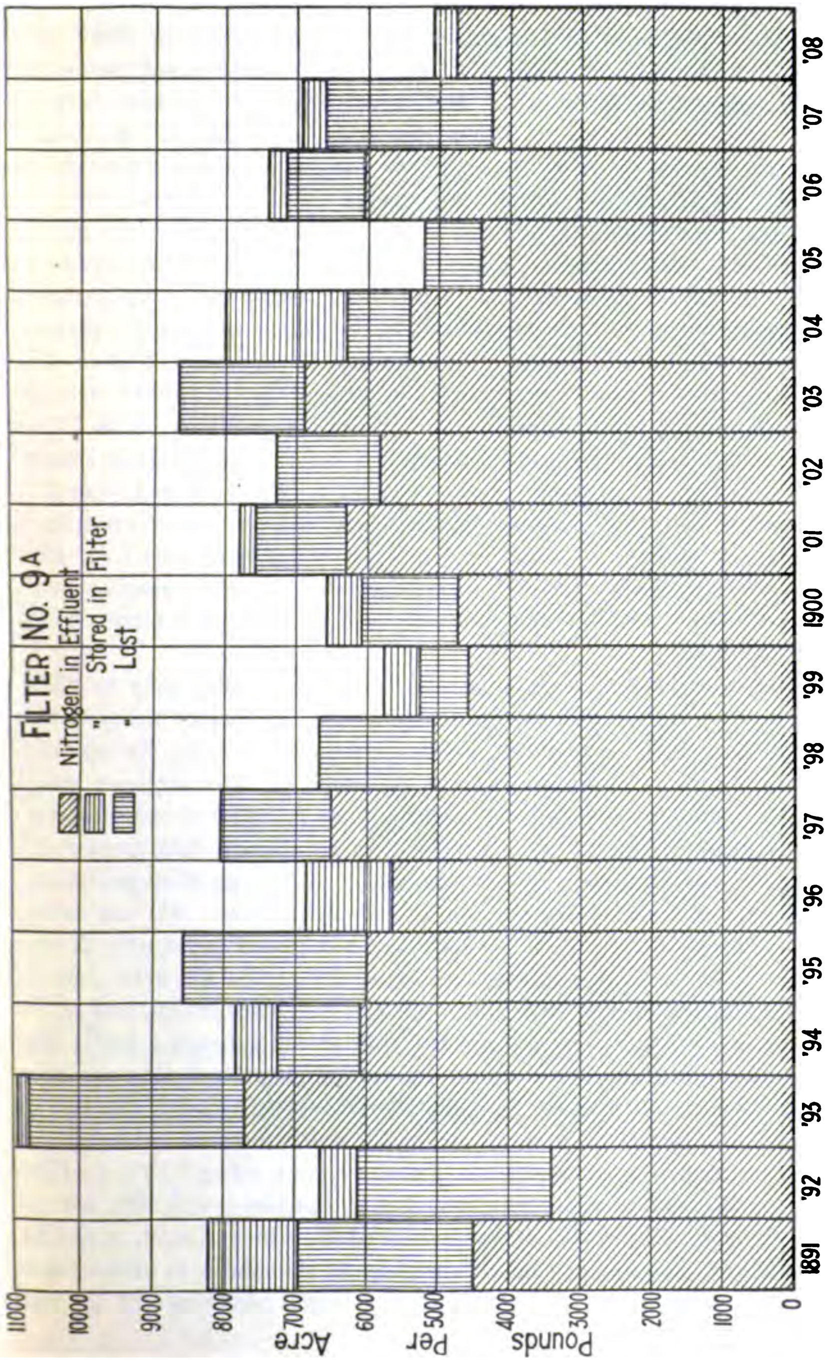


* No analysis of stored material made

gen previously stored has been oxidized and removed during 1907 and 1908 to such an extent from Filters Nos. 1 and 6 that the oxidized nitrogen in the effluents during these years has been greater than the unoxidized nitrogen in the sewage applied. Undoubtedly some of the nitrogen oxidized in the effluents each year comes from nitrogenous matter stored during previous years, matter that has been more thoroughly worked over than that more recently applied.

A very complete study has been made of the percentage of the nitrogen applied to Lawrence sand filters that appears in their effluents (1) in an oxidized condition; (2) in an unoxidized condition; (3) of the percentage of applied nitrogen removed by the filter; and (4) of the amount stored. Results of this study have been given in the last four reports. It is evident from this study, covering twenty-one years, that the average amount of the applied nitrogen nitrified while the sewage is passing through the filters is about 55 per cent., although it was considerably less than this during the first year or two of operation. During the first year or two, moreover, a very much larger percentage of the applied nitrogen was stored than during subsequent years, and for this reason a smaller percentage of oxidized and unoxidized nitrogen appeared in the effluents of these filters than during subsequent years. For example, Filter No. 1 during its first year of operation, as shown by following tables, stored or otherwise removed from the applied sewage 63 per cent. of its total nitrogen; that is to say, only 37 per cent. of the applied nitrogen, whether oxidized or unoxidized, appeared in the filter effluent. With Filter No. 2, 68 per cent. of the nitrogen applied during its first year of operation and 58 per cent. of that applied during its second year did not appear in its effluent. With Filter No. 4, 81 per cent. of the nitrogen applied during the first year and 75 per cent. of that applied during the second year did not appear in its effluent. With Filter No. 6, 70 per cent. and with Filter No. 9A, 75 per cent. of the nitrogen applied during the first year did not appear in its effluent. Taking, however, the entire series of years up to the end of 1908, the average amount of the applied nitrogen not appearing in the effluents is much less; namely, 28 per cent. in the case of Filter No. 1, 31 per cent. in the case of Filter No. 2, 41 per cent. in the case of Filter No. 4, 30 per cent. in the case of Filter No. 6, and 26 per cent. in the case of Filter No. 9A. A study of the tables given on pages 317–321, inclusive, will show also that, in the case of Filters Nos. 1, 2, 4 and 6, the amount not appearing has been slight, during the past five or six years, as compared with the first fifteen years; that is, nearly as much has appeared in the effluents yearly as has been applied during recent years.

Diagram No. 15.



During the first years of operation of these filters the average percentage of the applied nitrogen appearing as nitrates in their effluents was considerably less than during subsequent years, as shown by the tables just mentioned. For instance, during the first full calendar year of operation of Filter No. 1 the percentage of the applied nitrogen appearing as nitrates in its effluent was 30, although the average for the entire period of operation up to the end of 1908 has been 59. The nitrates for the first full year of operation of Filter No. 2 contained 25 per cent. of the applied nitrogen, while the average for the entire period up to date is about 58 per cent.; and similar figures are shown by most of the other sand filters that have been in operation for many years at the station. As the filters became older, that is, after they had been in use some years, the percentage of applied nitrogen appearing as nitrates increased. In different years from 65 to 77 per cent. of the applied nitrogen appeared as nitrates in the filter effluent. High nitrification followed the rejuvenating of Filters Nos. 1, 6 and 9A in 1893, when clogged surface sand was last removed, and the maximum amount of nitrates in most of the filter effluents appeared in 1906. (See tables on pages 290–292.) Of the nitrogen not appearing in the effluents only a small percentage is actually stored in the filters, as will be shown later.

Thus far in this discussion attention has been called only to Filters Nos. 1, 2, 4, 6, 9A and 10. Special studies were made, however, with Filters Nos. 14A, 19 and 100, filters constructed of sand, the operation of which will be discussed later in this report. The nitrogen results of these filters are discussed here especially, as the rates of operation were much greater than in the filters already mentioned, this greater rate being followed in a study of the purification of sewage after preliminary treatment, to remove certain matters in suspension. All the sewage applied to Filter No. 14A, for instance, had passed previously through a coke strainer; all the sewage applied to Filter No. 19, after Jan. 20, 1893, had been treated with chemicals to cause clarification, and all the sewage applied to Filter No. 100 had first passed through a septic tank. The tables show also the enormous amount of unoxidized nitrogen calculated as "units" applied to these filters, compared with the amount applied to Filters Nos. 1 to 10, inclusive, which received untreated sewage, the average units applied to Filter No. 14A being 1,177; to Filter No. 19, 599, and to Filter No. 100, 948, as compared with 283, 239 and 287, the average amounts in units applied to Filters Nos. 1, 6 and 9A, respectively. As a considerable percentage of the matter in suspension in the sewage had been removed, leaving a larger percentage of the total

organic matter applied in the form of the more easily oxidized organic matter in solution, the average percentage of oxidation in these filters has been somewhat greater than in Filters Nos. 1 to 10, inclusive, the highest average percentage being given by Filter No. 14A, namely, 69 per cent.

Filter No. 1.—Table showing Nitrogen applied and Nitrogen Changes.

Date.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Nitrogen applied.		Per Cent. of Applied Nitrogen.		
		Parts per 100,000.	Units.[1]	Not appearing in Effluent.	In Effluent.	
					Oxidized.	Un-oxidized.
1888,[2]	58.4	2.70	144	63.0	29.6	7.4
1889,	63.6	2.71	172	40.9	55.4	3.7
1890,	84.2	2.92	246	47.0	46.5	6.5
1891,	115.8	3.32	383	51.1	39.6	9.3
1892,	124.1	3.78	469	48.2	40.7	11.1
1893,	105.9	3.66	389	23.3	58.7	18.0
1894,	70.3	4.47	314	17.0	71.1	11.9
1895,	67.4	5.06	341	27.4	54.9	17.7
1896,	56.8	4.81	273	28.6	63.1	8.3
1897,	62.1	4.95	308	33.1	55.0	11.9
1898,	60.5	4.29	259	27.8	62.0	10.2
1899,	54.8	4.32	237	27.1	59.5	13.4
1900,	51.9	4.95	257	31.7	55.3	13.0
1901,	57.2	5.40	309	24.8	34.8	40.4
1902,	56.6	4.95	280	18.6	45.0	36.4
1903,	72.0	4.84	349	8.7	58.1	33.2
1904,	54.9	5.31	292	9.0	62.8	28.2
1905,	59.6	3.60	215	8.4	78.0	13.6
1906,	54.1	5.17	280	5.7	83.3	11.0
1907,	50.7	4.76	241	–[3]	86.0	21.4
1908,	59.1	3.05	180	–[3]	96.1	13.8
Average,	68.3	4.24	283	28.5	58.8	16.2

[1] An arbitrary factor, obtained by multiplying the rate, in thousand gallons per acre daily, for six days in a week, by the total nitrogen applied in parts per 100,000.

[2] Filter started Jan. 10, 1888.

[3] More nitrogen in effluent than in applied sewage.

Filter No. 2.—Table showing Nitrogen applied and Nitrogen Changes.

DATE.	Volume of Sewage applied (Thousand Gallons per Acre daily).	NITROGEN APPLIED.		PER CENT. OF APPLIED NITROGEN.		
				Not appearing in Effluent.	IN EFFLUENT.	
		Parts per 100,000.	Units.		Oxidized.	Un-oxidized.
1888,[1]	28.2	2.70	76	68.5	25.2	6.3
1889,	32.0	2.71	87	58.3	40.6	1.1
1890,	59.6	2.92	174	43.2	55.8	1.0
1891,	50.8	3.32	169	59.0	31.8	9.2
1892,	24.5	3.78	93	47.9	38.4	13.7
1893,	40.3	3.66	147	24.9	67.5	7.6
1894,	43.9	4.47	196	33.0	63.9	3.1
1895,	33.7	5.06	171	36.8	53.0	10.2
1896,	37.0	4.81	178	25.0	68.1	6.9
1897,	37.0	4.95	183	46.5	49.3	4.2
1898,	38.3	4.29	164	41.8	53.8	4.4
1899,	34.4	4.32	149	40.0	51.2	8.8
1900,	33.8	4.95	167	25.7	67.0	7.3
1901,	36.3	5.40	196	33.4	44.8	21.8
1902,	31.2	4.95	154	18.7	53.7	27.6
1903,	34.7	4.84	168	9.3	66.5	24.2
1904,	32.6	5.31	173	26.2	43.8	30.0
1905,	33.1	3.60	119	1.1	79.2	19.7
1906,	35.0	5.17	181	8.9	86.8	4.3
1907,	29.8	4.71	140	2.8	73.0	24.2
1908,	29.4	3.19	94	0.1	98.0	1.9
Average,	36.0	4.24	151	31.0	57.7	11.3

[1] Filter started Dec. 19, 1887.

Filter No. 4.—Table showing Nitrogen applied and Nitrogen Changes.

1888,[1]	28.7	2.70	76	80.8	8.1	11.1
1889,	20.0	2.71	54	75.3	23.6	1.1
1890,	33.2	2.92	97	55.8	43.5	0.7
1891,	41.4	3.32	137	53.3	43.6	3.1
1892,	41.8	3.87	162	68.7	17.6	13.7
1893,	32.3	3.81	123	58.8	38.0	3.2
1894,	20.1	4.47	90	56.0	34.2	9.8
1895,	15.8	4.90	77	56.5	42.1	1.4
1896,	19.0	5.01	95	39.7	55.5	4.8
1897,	19.4	5.01	97	39.3	58.5	2.2
1898,	19.3	4.30	83	46.0	52.8	1.2
1899,	16.8	4.01	68	46.7	51.1	2.2
1900,	17.8	5.06	90	33.9	64.5	1.6
1901,	20.4	5.50	112	41.3	49.8	8.9
1902,	19.6	4.95	97	14.6	62.2	23.2
1903,	18.2	4.84	88	30.1	64.1	5.8
1904,	18.0	5.31	96	30.1	64.8	5.1
1905,	20.6	3.60	74	8.6	85.8	5.6
1906,	19.0	5.17	98	9.5	89.5	1.0
1907,	18.4	4.71	87	1.6	88.8	9.6
1908,	18.7	3.19	60	13.1	85.3	1.6
Average,	22.8	4.26	93	40.9	53.5	5.6

[1] Filter started Dec. 19, 1887.

Filter No. 5A.— Table showing Nitrogen applied and Nitrogen Changes.

Date.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Nitrogen applied.		Per Cent. of Applied Nitrogen.		
		Parts per 100,000.	Units.	Not appearing in Effluent.	In Effluent.	
					Oxidized.	Un-oxidized.
1891,[1]	64.0	5.15	330	76.2	17.2	6.6
1892, ...	94.4	3.87	366	48.1	30.2	21.7
1893, ...	119.2	3.81	454	32.6	48.0	19.4
1894, ...	90.6	4.47	405	23.7	60.6	15.7
1895, ...	68.3	4.90	335	28.0	50.8	21.2
1896, ...	56.1	5.01	281	16.3	61.9	21.8
1897, ...	58.8	5.01	295	26.3	54.8	18.9
1898, ...	83.2	4.10	341	36.6	28.5	34.9
Average, . . .	79.3	4.54	351	36.0	44.0	20.0

[1] Filter started Sept. 14, 1891; stopped Feb. 28, 1898.

Filter No. 5B. Table showing Nitrogen applied and Nitrogen Changes.

Date.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Parts per 100,000.	Units.	Not appearing in Effluent.	Oxidized.	Un-oxidized.
1898,[1]	72.8	4.08	298	40.5	42.9	16.6
1899, ...	81.7	4.01	327	19.2	58.8	22.0
1900, ...	109.2	5.06	553	25.5	56.7	17.8
1901, ...	131.5	5.50	722	27.0	45.0	28.0
1902, ...	116.9	4.95	579	18.5	58.9	22.6
1903, ...	90.0	4.84	435	6.3	61.0	32.7
1904, ...	72.6	5.31	386	5.4	66.7	27.9
1905, ...	68.1	3.38	230	–[2]	86.0	31.4
Average, . . .	92.8	4.64	441	20.3	59.5	24.9

[1] Filter started March 5, 1898; stopped July 11, 1905.
[2] More nitrogen in effluent than in applied sewage.

Filter No. 5C.—Table showing Nitrogen applied and Nitrogen Changes.

Date.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Parts per 100,000.	Units.	Not appearing in Effluent.	Oxidized.	Un-oxidized.
1905,[1]	54.2	3.81	207	33.2	65.8	1.0
1906, ...	52.9	5.17	273	–[2]	93.3	7.2
1907, ...	44.9	4.71	211	–[2]	115.0	14.0
1908, ...	46.5	3.19	148	–[2]	126.5	19.4
Average, . . .	49.6	4.22	210	-	100.1	10.4

[1] Filter started July 20, 1905. [2] More nitrogen in effluent than in applied sewage.

Filter No. 6. — Table showing Nitrogen applied and Nitrogen Changes.

Date.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Nitrogen applied.		Per Cent. of Applied Nitrogen.		
		Parts per 100,000.	Units.	Not appearing in Effluent.	In Effluent.	
					Oxidized.	Un-oxidized.
1888,[1]	39.5	2.70	107	70.4	26.3	3.3
1889,	41.0	2.71	111	46.4	52.5	1.1
1890,	55.2	2.92	161	55.8	42.1	2.1
1891,	61.2	3.32	203	46.0	40.3	5.7
1892,	46.9	4.07	191	43.5	40.5	16.0
1893,	85.5	3.97	340	29.5	57.7	12.8
1894,	54.3	4.53	246	26.6	67.8	5.6
1895,	57.6	4.72	272	29.0	55.4	15.6
1896,	56.8	5.50	312	36.4	52.0	11.6
1897,	60.5	5.02	304	33.7	57.1	9.2
1898,	65.6	4.08	268	26.3	67.3	6.4
1899,	59.4	3.95	234	26.1	65.3	8.6
1900,	51.7	5.02	260	30.6	57.7	11.7
1901,	57.6	5.49	316	29.0	43.3	27.7
1902,	58.0	4.95	287	15.8	44.6	39.6
1903,	70.2	4.84	340	17.9	52.4	29.7
1904,	54.4	5.31	289	14.8	57.4	27.8
1905,	56.0	3.60	202	8.9	75.3	15.8
1906,	53.8	5.17	278	4.0	82.7	13.3
1907,	39.4	4.76	188	9.0	61.2	29.8
1908,	38.8	3.05	118	–[2]	103.0	7.5
Average,	55.4	4.27	239	30.0	57.2	14.3

[1] Filter started Jan. 12, 1888. [2] More nitrogen in effluent than in applied sewage.

Filter No. 9A. — Table showing Nitrogen applied and Nitrogen Changes.

1890,[1]	110.0	3.38	372	74.9	2.1	23.0
1891,	95.8	3.32	318	45.5	40.3	14.2
1892,	68.1	3.77	257	48.8	35.3	15.9
1893,	111.7	3.80	424	29.8	51.5	18.7
1894,	68.8	4.40	303	22.4	66.0	11.6
1895,	66.0	5.02	332	30.1	51.0	18.9
1896,	56.3	4.71	265	17.7	68.5	13.8
1897,	61.5	5.07	312	19.3	67.7	13.0
1898,	74.2	3.48	258	24.1	65.0	10.9
1899,	59.5	3.75	223	21.0	64.3	14.7
1900,	48.8	5.22	255	28.6	58.6	12.8
1901,	53.9	5.60	302	19.3	39.3	41.4
1902,	57.0	4.95	282	20.0	46.5	33.5
1903,	69.2	4.84	335	20.5	54.1	25.4
1904,	53.8	5.31	286	26.8	55.5	17.7
1905,	55.3	3.60	199	14.8	72.5	12.7
1906,	52.8	5.17	273	12.7	76.3	11.0
1907,	55.7	4.76	265	9.5	73.1	17.4
1908,	63.7	3.05	194	6.4	81.5	12.1
Average,	67.5	4.38	287	25.9	56.3	17.8

[1] Filter started Nov. 18, 1890.

Filter No. 10.— Table showing Nitrogen applied and Nitrogen Changes.

Date.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Nitrogen applied.		Per Cent. of Applied Nitrogen.		
		Parts per 100,000.	Units.	Not appearing in Effluent.	In Effluent.	
					Oxidized.	Un-oxidized.
1894,[1]	40.0	6.17	247	48.8	45.9	5.3
1895,	36.7	5.02	184	38.8	48.5	12.7
1896,	28.2	4.71	133	27.3	65.1	7.6
1897,	29.5	5.07	149	30.1	60.4	9.5
1898,	28.6	3.48	100	14.1	77.3	8.6
1899,	25.0	3.75	94	19.7	68.3	12.0
1900,	25.5	5.22	133	30.9	62.0	7.1
1901,	27.8	5.60	156	28.5	47.7	23.8
1902,	26.4	4.95	131	30.3	52.5	17.2
1903,	21.7	4.84	105	30.3	56.0	13.7
1904,	17.2	5.31	91	31.5	52.2	16.3
1905,	20.9	3.60	75	24.2	63.6	12.2
1906,	23.9	5.17	124	27.5	64.8	7.7
1907,	29.4	4.71	138	38.2	43.8	18.0
1908,	36.1	3.19	115	22.0	73.0	5.0
Average,	27.8	4.72	132	29.5	58.7	11.8

[1] Filter started July 18, 1904.

Filter No. 14A.— Table showing Nitrogen applied and Nitrogen Changes.

[Strained sewage applied.]

1894,[1]	345.1	3.43	1,180	21.6	72.6	5.8
1895,	307.1	4.74	1,452	36.4	55.1	8.5
1896,	279.9	4.29	1,200	27.8	65.0	7.2
1897,	279.7	4.28	1,197	24.5	68.0	7.5
1898,	298.0	2.88	857	12.5	83.0	4.5
Average,	302.0	3.92	1,177	24.6	68.7	6.7

[1] Filter started Jan. 12, 1894.

Filter No. 19.[1] — Table showing Nitrogen applied and Nitrogen Changes.

[Regular sewage and chemically treated sewage applied.]

1890,[1]	58.2	2.92	170	37.0	57.2	5.8
1891,	90.6	3.32	301	34.4	63.5	2.1
1892,	51.2	3.56	183	38.0	60.0	2.0
1894,	253.2	4.09	1,036	29.4	60.8	9.8
1895,	196.9	5.22	1,028	31.9	60.6	7.5
1896,	189.6	5.43	1,030	33.2	60.7	6.1
1897,	190.0	3.92	745	21.6	70.5	7.9
Average,	147.1	4.07	599	32.2	61.9	5.9

Average 1890 to 1892, inclusive.

	66.7	3.27	218	36.7	60.2	3.1

Average 1894 to 1897, inclusive.

	207.4	4.67	969	29.0	63.2	7.8

[1] Filter started Jan. 28, 1890. Regular sewage applied until 1894, after that date sewage clarified by chemicals.

Filter No. 100. — Table showing Nitrogen applied and Nitrogen Changes.

[Septic sewage A applied.]

Date.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Nitrogen applied.		Per Cent. of Applied Nitrogen.		
		Parts per 100,000.	Units.	Not appearing in Effluent.	In Effluent.	
					Oxidized.	Un-oxidized.
1898,[1]	180.0	4.84	629	20.2	52.1	27.7
1899, ...	265.4	4.00	1,062	14.3	68.7	17.0
1900, ...	264.3	5.97	1,578	37.5	52.9	9.6
1901, ...	254.9	4.90	1,249	17.7	54.9	27.4
1902, ...	298.4	4.59	1,369	18.5	63.6	17.9
1903, ...	270.3	3.85	1,041	17.1	70.7	12.2
1904, ...	222.5	5.75	1,279	44.7	35.7	19.6
1905, ...	155.4	4.10	637	14.4	69.5	16.1
1906, ...	194.7	4.26	829	5.5	75.5	19.0
1907, ...	76.1	5.42	412	7.3	77.0	15.7
1908, ...	63.3	5.44	344	3.6	90.5	5.9
Average, . . .	199.6	4.83	948	18.3	64.6	17.1

[1] Filter started Jan. 1, 1898; stopped March 1, 1908.

The following table summarizes many nitrogen results for the entire period of operation of the filters already discussed and gives also the average rate of operation of each filter.

Table showing Average Nitrogen Conversion, etc., of Various Filters.

Filter Number.	Period operated.	Volume of Sewage applied (Thousand Gallons per Acre daily).	Nitrogen in Applied Sewage (Parts per 100,000).	Per Cent. of Applied Nitrogen.			
				In Effluent.		Stored and Lost.[1]	Oxidized and Lost.
				Oxidized.	Un-oxidized.		
1, ...	1888-1908,	68.3	4.24	58.8	16.2	25.0	87.3
2, ...	1888-1908,	36.0	4.24	57.7	11.3	31.0	88.7
4, ...	1888-1908,	22.8	4.26	53.5	5.6	40.9	94.4
5A, ...	1891-1898,	79.3	4.54	44.0	20.0	36.0	80.0
5B, ...	1898-1905,	92.8	4.64	59.5	24.9	15.6	79.8
5C, ...	1905-1908,	49.6	4.22	100.1	10.4	–[2]	100.1
6, ...	1888-1908,	55.4	4.27	57.2	14.3	28.5	87.2
9A, ...	1890-1908,	67.5	4.38	56.3	17.8	25.9	82.2
10, ...	1894-1908,	27.8	4.72	58.7	11.8	29.5	88.2
14A, ...	1894-1898,	302.0	3.92	68.7	6.7	24.6	93.3
19, ...	1890-1897,	147.1	4.07	61.9	5.9	32.2	94.1
100, ...	1898-1908,	199.6	4.83	64.6	17.1	18.3	83.9

[1] Nitrogen applied which did not appear in the effluent, including nitrogen stored in the sand and nitrogen set free.

[2] More nitrogen in effluent than in applied sewage.

NITROGEN STUDIES CONTINUED. — STORAGE AND DISAPPEARANCE OF NITROGEN.

In continuing this work, tables are given to illustrate further storage, oxidation, etc., of nitrogen in sand filters. The first of these tables shows the actual amount of nitrogen, expressed in pounds, which has been applied, *per acre* of filter surface, to sand Filters Nos. 1, 6 and 9A; stored in these filters; the amount removed by or disappearing from the filters; the amount appearing as nitrates or as unoxidized nitrogen in the effluents. These items are shown also by the diagrams. This table is of especial interest as showing (1) how little of the applied nitrogen remains stored in these filters, although this small percentage results in a course of years in an amount of stored nitrogen relatively large, and (2) how large a percentage of nitrogen is cared for or changed in other ways than by nitrification and by passing away as nitrates in the effluent of each filter. The tables given previously, on pages 317–322, inclusive, show the average amount of applied nitrogen not appearing in the effluents of Filters Nos. 1 to 10, inclusive, and also of Filters Nos. 14A, 19 and 100. These figures might lead to the belief that a much larger percentage of the applied nitrogen is stored than is really the case, as about 30 per cent. of the applied nitrogen does not appear in the effluents. The actual amounts stored, however, in Filters Nos. 1, 6 and 9A, are 3.5, 4.7 and 4.2 per cent., respectively, of the organic nitrogen that has been applied, these figures being determined by many duplicate sand analyses. Of this stored nitrogen, over 70 per cent. is found in the upper foot of sand of each filter, as shown by tables beyond. The percentage of nitrogen appearing as nitrates in the effluents has already been referred to. The amount of nitrogen appearing unoxidized in the effluents has varied greatly, as shown in the tables, and the amount which has disappeared, that is, which has neither been detected as oxidized or unoxidized nitrogen in the effluents nor as stored at the present time in the sand of each filter, has been a large and variable quantity. This disappearance of nitrogen is discussed in a later chapter, upon the "Bacteriology and Biochemistry of Sewage Purification."

Table showing Nitrogen, in Pounds per Acre, applied to, stored, appearing in Effluent, lost from Various Sand Filters, and Per Cent. of Nitrogen stored.

Date of Sand Analysis.	Days operated.	Pounds of Nitrogen.					
		Applied.	Stored in Sand.	In Effluent.	Lost.	In Effluent.	
						Oxidized.	Un-oxidized.
Filter No. 1.							
July 1, 1908, . .	6,432	155,860	5,429	129,093	21,338	90,420	38,673
Filter No. 6.							
July 1, 1908, . .	6,430	129,688	6,126	90,686	31,876	69,956	20,730
Filter No. 9A.							
July 1, 1908, . .	5,537	137,673	5,850	101,935	29,888	74,312	27,623

Per Cent. of Applied Nitrogen stored in Filter.

	Per Cent.
Filter No. 1, ...	3.5
Filter No. 6, ...	4.7
Filter No. 9A, ...	4.2

Table showing Amount of Organic Nitrogen, calculated from the Albuminoid Ammonia, in Pounds per Acre per Foot of Sand.

Date of Sand Analysis.	Days operated.	Organic Nitrogen in —						Per Cent. of Total which First Foot Yields.
		First Foot.	Second Foot.	Third Foot.	Fourth Foot.	Fifth Foot.	Total.	
Filter No. 1.								
July 1, 1908, .	6,432	3,944	860	225	158	152	5,339	73.8
Filter No. 6.								
July 1, 1908, .	6,430	4,547	790	482	307	-	6,126	74.2
Filter No. 9A.								
July 1, 1908, .	5,537	4,489	591	286	216	268	5,850	76.7
Filter No. 14A.								
Jan. 15, 1900, .	1,748	4,440	1,225	376	225	155	6,421	27.2
Filter No. 19.								
March 7, 1898, .	2,169	5,651	611	206	148	135	6,751	82.1
Filter No. 100.								
Dec. 3, 1907, .	3,107	2,696	1,050	528	306	-	4,580	67.8

Nitrification by Municipal Filters.

In the Lawrence filters, receiving strong but stale sewage, a greater per cent. of the applied nitrogen is nitrified than in the municipal filters of the State. From the surface of many of these municipal filters, moreover, much organic matter is raked and scraped from time to time, while no such removal has been made from the older Lawrence filters for fifteen years. The difference in nitrification at Lawrence is shown by comparing the percentage of applied nitrogen that is oxidized and that appears as nitrates in the effluents of these areas and in the Lawrence effluents. A study of this point in 1904[1] showed that at only one disposal area did 50 per cent. of the applied nitrogen appear in nitrified form in the effluent, and at few areas was even 30 per cent. of the applied nitrogen nitrified, the average amount in the effluents of fifteen areas being 25 per cent. The average amount of the total nitrogen unaccounted for at these areas, that is, that does not appear in their effluents, is much larger than at Lawrence. This shows plainly the effect of removal of much matter from the surface of these areas, as they certainly do not, judging by analyses of sand from different depths, store nitrogen any more rapidly than the station filters. The average amount removed, stored and lost by nitrogen liberation is over 61 per cent. of the nitrogen applied, judging by analyses of sewage and effluents covering a considerable number of years. In the calculation of results of these areas a certain error enters that is absent in connection with the Lawrence filters. This is the fact that, at the areas, a certain amount of ground water is mixed with the true sewage effluent. The amount of ground water in most of these effluents, however, is not great enough to decrease materially the figures of oxidized nitrogen or to increase the figures of unoxidized nitrogen.

Storage of Stable Matter. — Humus.

When the principal sand filters already discussed began to show clogging with organic matter, certain experiments were made to learn whether or not the organic matter in the sand would become oxidized and thus removed when this sand was allowed to rest without application of sewage, or when piled in ridges on the filter, or thrown out at one side. The results of these experiments, as stated in the early reports, showed that a certain percentage of this organic matter was thus oxidized but that much was very stable. Again, in 1903, 1904 and 1905, when clogging of the surface sand of the filters seemed to be serious, further studies were made. It was found at this time that sand

[1] Massachusetts State Board of Health report for 1904, pp. 223, 224.

removed from these filters lost in the course of a month or two a considerable percentage of its stored nitrogen, but that a point was soon reached when it decreased little if any. Further experiments were made by constructing filters of this clogged sand and by passing small volumes of *water* through them, and by causing in various ways conditions apparently very favorable for the oxidation and removal of nitrogen. Even such treatments, however, did not succeed in causing the oxidation of this stable nitrogenous matter. The special studies made in 1903, 1904 and 1905 are described in full in the reports for those years, and show that, in spite of all efforts to remove nitrogen from clogged sand by oxidation, much of this nitrogenous matter was affected but slightly, for little nitrogen came from the filters with their effluents after the first few weeks of operation, notwithstanding the large amount of organic nitrogenous matter remaining upon the sand.

Ten small filters of clogged sand, Nos. 265 to 274, inclusive, were started to study this removal of stable matters by oxidation. The results obtained by operating four of these filters at low rates for sixteen months with water are shown in the following table: —

Table showing Nitrogen in Sand Filters Nos. 265 to 268, inclusive, at Different Periods.

[Parts per 100,000.]

	Total Nitrogen.			
	Filter No. 265.	Filter No. 266.	Filter No. 267.	Filter No. 268.
1904.				
Start,	215.70	176.70	84.43	91.43
July 26,	63.65	78.70	61.58	63.65
Aug. 29,	62.62	71.11	63.51	64.09
Dec. 15,	64.40	78.88	64.50	57.30
1905.				
March 1,	64.19	–	56.73	53.47
July 10,	–	–	57.07	–
Oct. 11,	50.62	83.47	58.45	57.00
Total parts nitrogen removed by filtration,	165.10	93.23	27.70[1]	34.43
Parts nitrogen appearing in effluent as inorganic nitrogen,	87.67	32.20	26.17	15.00
Parts nitrogen removed as organic and free nitrogen,	127.43	61.03	1.53	19.43
Per cent. removed in first three months,	70.00	55.40	27.00	30.40
Per cent. removed in sixteen months,	76.50	52.70	30.80	37.60

[1] Using March 1 analysis.

During 1904 and 1905 quite complete studies were made, also, of the decrease in nitrogen when surface sand of the three original filters was piled in ridges, to which no sewage was applied. Between Oct. 10, 1904, and Sept. 16, 1905, in the case of Filter No. 1, and between

June 8, 1904, and Sept. 13, 1905, in the cases of Filters Nos. 6 and 9A, periods of eleven and fourteen months, respectively, frequent determinations of the amount of free ammonia and nitrogen in the sand of the ridges were made. The results are given in a following table, and show that the stable nitrogenous matters in this sand remained almost unchanged during the entire period of eleven months. Slight fluctuations in the amount present are indicated, but these fluctuations were probably due to the great difficulty in obtaining for examination absolutely fair and uniform samples. These tables also contain determinations of loss on ignition as well as of fatty matters, and the bodies determined by these analyses also decreased little, if any, during this period.

Analyses on Different Dates of Sand from Ridges of Filter No. 1.

[Parts per 100,000.]

Date.	Free Ammonia.	Albuminoid Ammonia.	Kjeldahl Nitrogen.	Kjeldahl Ratio.	Loss on Ignition.	Fats.
1904.						
Oct. 10,	1.34	47.00	-	-	2.58	-
Nov. 15,	1.47	45.90	78.42	55.3	2.43	-
1905.						
March 15,	1.63	48.38	-	-	2.42	-
April 25,	2.78	52.07	-	-	-	-
June 1,	1.99	55.76	86.40	52.9	2.52	-
June 22,	1.57	47.67	76.43	50.1	2.42	-
July 19,	1.68	54.15	84.94	52.3	2.81	59.5
Aug. 24,	2.39	59.60	85.90	56.8	2.40	71.5
Sept. 16,[1]	3.15	50.85	79.32	52.6	-	69.5
Sept. 16,[2]	1.61	50.15	70.88	58.0	-	50.5

[1] Average upper 3 inches. [2] Average upper 6 inches.

Analyses on Different Dates of Sand from Ridges of Filter No. 6.

Date.	Free Ammonia.	Albuminoid Ammonia.	Kjeldahl Nitrogen.	Kjeldahl Ratio.	Loss on Ignition.	Fats.
1904.						
June 8,	-	118.50	-	-	-	-
Aug. 8,	-	65.20	-	-	-	-
Oct. 10,	1.98	76.72	-	-	4.01	-
Nov. 15,	2.34	68.69	101.70	56.5	3.32	-
1905.						
March 15,	2.51	67.30	-	-	3.20	-
April 25,	5.07	70.52	-	-	-	-
June 1,	1.85	78.98	124.10	52.2	3.45	-
June 22,	2.06	69.92	101.40	56.5	2.61	64.0
Aug. 21,	1.90	72.40	116.40	53.2	3.19	74.0

Analyses on Different Dates of Sand from Ridges of Filter No. 9A.

[Parts per 100,000.]

Date.	Free Ammonia.	Albuminoid Ammonia.	Kjeldahl Nitrogen.	Kjeldahl Ratio.	Loss on Ignition.	Fats.
1904.						
June 8,	-	62.50	-	-	-	-
Aug. 8,	-	55.00	-	-	-	-
Oct. 12,	1.77	59.39	-	-	2.62	-
Nov. 15,	1.10	58.84	89.32	54.0	2.54	-
1905.						
March 15,	2.10	55.08	-	-	2.41	-
April 25,	2.15	57.40	-	-	-	-
June 1,	1.68	70.15	104.00	55.8	2.76	-
June 22,	2.37	55.31	85.17	53.3	2.93	72.5
July 10,	2.86	64.50	94.30	56.1	2.80	73.5
July 17,	2.43	66.15	93.56	55.4	2.85	73.0
Sept. 13,	2.68	57.35	83.64	56.2	2.56	-

The work upon the removal of organic matter seems to show clearly that by systematic resting of the upper sand of sewage filters a considerable percentage of the nitrogenous organic matter may be, in some instances, removed by bacterial action. Still, when such filters have been in use for many years, and the accumulated organic matter has undergone this long-continued bacterial action that is always taking place in such filters, most of this matter is found to be stable in nature and difficult to oxidize. Undoubtedly a certain portion of it is as stable as humus; in other words, as stable as soil nitrogen which remains year after year at practically the same point unless exhausted by severe cropping. It is the residual organic matter remaining after the easily changed matter has been removed by bacterial action. Notwithstanding this accumulation of stable matter it has been possible to keep Filters Nos. 1, 2, 4 and 6 in operation for twenty-one years without sand removal, except in 1892 and 1893, and, judging from the condition of the filters at present, satisfactory operation for a number of years without further removal of surface sand is possible and probable. It was predicted in the report for 1904 that some of this stored organic matter would become in the course of time more easily oxidized, and the large amount of oxidized nitrogen in the 1907–1908 effluents would seem to show this to be the fact.

Further Studies of Storage in Sand Filters of Organic Matters of Different Kinds, etc. — Accumulation of Carbonaceous and Fatty Matters.

Thus far this discussion has been confined entirely to the application of, storage of and removal of nitrogen. Nitrogen forms but a small percentage, however, of the organic matter present in sewage and stored in filters. The reason that it has so prominent a place in all studies of

water and sewage, and especially of sewage purification, is that it is the chief constituent of matter that is easily changed; matter which causes odors when putrefaction occurs, and matter, the change of which from one form to another, denotes the transformation of a polluted liquid, such as sewage, to a well-purified filter effluent. As a matter of fact, however, the clogging which occurs in sand filters is due chiefly to carbonaceous matter, fatty and otherwise. When Filters Nos. 1, 6 and 9A were first put into operation a determination was made of the total organic matter on the sand grains. During 1908 determinations were made again with samples collected from different depths of these same filters, and the results are compared here. At the beginning of operation, Filter No. 1 had apparently upon its sand grains 467 pounds, Filter No. 6, 845 pounds, and Filter No. 9A, 487 pounds of organic matter. These determinations were made by loss on ignition methods, however, and they indicate undoubtedly the presence of more organic matter than was actually present. The same method used in 1908 showed 1,250 pounds of organic matter stored in Filter No. 1, or an increase of 783 pounds; 1,463 pounds stored in Filter No. 6, or an increase of 618 pounds; and 1,077 pounds stored in Filter No. 9A, or an increase of 590 pounds. In the following table these figures are given, together with the amounts of nitrogen stored in pounds; and the small amount of the latter compared with the total organic matter is most marked. The table shows, furthermore, not only nitrogen stored at the present time but the amount stored twelve years ago, in 1896; also the amount of fatty matters found stored in the filters at different times, namely, in 1892, 1894 and 1907. Most of the fatty matters stored in Filters Nos. 1 and 6, however, up to the end of 1892, were in the upper foot of sand, and were removed with the sand from the surface of these filters in 1892 and 1893.

Organic Nitrogen and Organic Matter stored in 1896 and 1908 in Filters Nos. 1, 6 and 9A, corrected for Amount in Original Sand.

	Filter No. 1.	Filter No. 6.	Filter No. 9A.
1896.			
Stored nitrogen (pounds),	10	22	17
1908.			
Stored nitrogen (pounds),	27	31	29
Organic matter stored during operation (pounds),	783	618	590

Fats stored in Filters Nos. 1, 6 and 9A at Different Intervals (Pounds).

January, 1892,	16.0	14.0	–
October, 1894,[1]	4.0	2.0	11.7
October, 1907,	19.3	23.3	17.6

[1] Most of the fatty matters stored up to 1893 were removed with the surface sand removal in 1892 and 1893.

Carbon Storage.

Accurate determinations of the carbonaceous constituents of the organic matter stored in these three filters, namely, Nos. 1, 6 and 9A, have been made by combustion furnace analyses, and following tables give the figures of carbon, and, for the purpose of comparison, determinations of organic matter by the loss on ignition method. These tables show that at least 75 per cent. of the stored carbonaceous matters are in the first foot in depth of each filter, and that the amount of carbon stored, in pounds, is from one-third to one-half as great in Filter No. 1 as that of organic matter as shown by the loss on ignition method.

Table showing Amount of Carbon, in Pounds per Acre per Foot of Sand, in Filters Nos. 1, 6 and 9A.

Date.	Carbon in —						Per Cent. of Total which First Foot yields.
	First Foot.	Second Foot.	Third Foot.	Fourth Foot.	Fifth Foot.	Total.	
Filter No. 1.							
Oct. 1, 1907, . . .	43,080	5,930	2,710	2,400	2,450	56,570	76.2
Filter No. 6.							
Oct. 1, 1907, . . .	58,280	10,520	5,590	3,900 [1]	-	78,290	74.4
Filter No. 9A.							
Oct. 1, 1907, . . .	50,800	4,380	3,260	3,540	1,290 [1]	63,270	80.3

[1] Six inches only.

Total Organic Matter stored, in Pounds per Acre per Foot of Sand, in Large Filters, as determined by Loss on Ignition, corrected for Organic Matter in Original Sand.

Filter No. 1.							
July 1, 1908, . . .	104,520	21,800	11,100	5,800	13,340	156,560	66.7
Filter No. 6.							
July 1, 1908, . . .	106,260	4,620	-	15,920	-	126,800	83.8
Filter No. 9A.							
July 1, 1908, . . .	107,140	8,780	840	420	7,200	124,380	86.2

Many analyses of the organic matter stored in these filters show that while cellulose contains 44.4 per cent. of carbon, 6.2 of hydrogen and 49.4 per cent. of oxygen, the carbonaceous organic matters in filters contain 47.8 per cent. of carbon, 6.4 per cent. of hydrogen and 46.9 per cent. of oxygen; that is, the per cent. of carbon is somewhat higher in this organic matter than in cellulose, and this fact is due probably to the presence of bodies similar to cellulose but containing a somewhat greater per cent. of carbon.

In further studies of this organic matter many determinations of the amount of fat, carbon, hydrogen, loss on ignition, etc., present in sewage sludge and the sand from Filters Nos. 1, 6 and 9A were made. These results are shown in a following table.

Summarizing, it can be said that there is a very large amount of fatty matter in sludge, and that it varies from 29 to 56 per cent. in the total organic matter in the samples of sludge examined; but, on the other hand, the stored organic matter in the filters contains but comparatively little fat, none of the samples of sand examined from these filters having more than 7.5 per cent. as much fat as carbon, the average being about 5 per cent. of the carbon present. The table following shows but a small amount of fatty matter in the sediment coming from contact and trickling filters, the figures indicating the great fat destruction going on in these filters. This will be discussed further in the chapter on "Trickling Filters."

Table showing Relation between Fats and Organic Matter in Sewage Sludge, Sediment from Contact and Trickling Filters, and Sands from Experimental Sewage Filters at Lawrence.

Sample of —	Per Cent. of —			Per Cent. which Fats are of Loss on Ignition.	Per Cent. which Fats are of Carbon.	Per Cent. Carbon in Fats.	Per Cent. Carbon in Fats is of Total Carbon.
	Carbon.	Fats.	Loss on Ignition.				
Andover sludge,	27.00	19.700	49.600	39.30	73.00	12.20	45.30
Regular Lawrence sewage sludge,	38.90	22.200	69.500	32.20	57.10	13.80	35.50
Sediment from Filter No. 136,	13.70	0.120	32.900	0.36	0.88	0.07	0.50
Sediment from Filter No. 137,	18.60	0.410	38.700	1.06	2.21	0.25	1.30
Sediment from Filters Nos. 135-136,	22.20	2.370	43.800	5.40	10.70	1.51	6.80
Sediment from Filter No. 221,	16.60	3.360	34.900	9.62	20.20	2.10	12.60
Sand of Filter No. 1, average,	0.256	0.017	0.554	3.07	6.64	-	-
Sand of Filter No. 6, average,	0.428	0.024	0.838	2.86	5.61	-	-
Sand of Filter No. 9A, average,	0.300	0.017	0.604	2.81	5.67	-	-

SAND REMOVAL DIRECTLY PROPORTIONAL TO AMOUNT OF ORGANIC MATTER APPLIED, ESPECIALLY THAT IN SUSPENSION.

With sand filters of a reasonable and equal depth, constructed of the same or similar grades of sand, the rate of operation that can be maintained year after year with satisfactory results depends upon the strength of the sewage, and particularly upon the matters in suspension in the sewage. If we take for illustration Filter No. 1, which has been operated at an average rate of 68,300 gallons per acre daily during the twenty-one years covered by this review, sand removal has been necessary only in 1892 and 1893, when the rates had been nearly twice this average for several years. During these twenty-one years the total *organic* nitrogen of the average yearly sewage applied has averaged 1.41 parts per 100,000, the highest amount occurring in 1897, namely, 1.65 parts, and the lowest in 1908, namely, 0.90 part. Of the organic nitrogen applied to this filter 45 per cent. has been in solution and 55 per cent. in suspension, the amounts varying to a considerable extent during different years, but in only five of the twenty-one years has more organic nitrogen been in solution in the applied sewage than in suspension. (See page 335.) The larger the amount in solution, the greater is the daily work of the filter, other things being equal, and, with the larger amount in suspension, the greater is the accumulated work to be done by the filter, unless such accumulations are eliminated by sand removal. Rates of filtration can be much increased with the removal of the matters in suspension in the applied sewage. Filters Nos. 14A, 19 and 100, for instance, which received strained, chemically clarified and septic sewage, respectively, could be operated at greater rates than Filter No. 1, for two reasons: first, the smaller amount of organic matter per volume of sewage applied, and secondly, the much smaller amount in suspension. The sewage applied to these three filters contained 55, 71 and 60 per cent. as much organic nitrogen, respectively, as that applied to Filter No. 1, and, furthermore, only 32, 41 and 37 per cent. as much of this organic nitrogen was in suspension as in the sewage of Filter No. 1. The average rates of operation of these filters during the period discussed here were as follows: Filter No. 1, 68,300, Filter No. 14A, 276,000, Filter No. 19, 162,000, and Filter No. 100, 213,000 gallons per acre daily. The following table shows the number of days that each one of these filters was operated, the volume of sewage applied in million gallons per acre for the total period covered, the depth of sand removed in inches, etc. Studying the table, it will be noted that a greater volume of sewage per acre of surface was applied to Filter No. 14A during its period of operation of five and one-half years than was applied to Filter No. 1 during twenty-one years. The volume per acre applied to Filter No. 19 during

its period of operation of eight years was somewhat less, while the volume applied to Filter No. 100 per acre during its period of operation of ten years was 50 per cent. greater than the volume applied per acre to Filter No. 1 during twenty-one years. From these filters, 9, 13, 16 and 12 inches of sand were removed, respectively. The number of cubic yards of sand removed per million gallons of sewage applied to these filters, Nos. 1, 14A, 19 and 100, was 2.71, 3.63, 5.24 and 2.37, respectively. In order to keep Filters Nos. 14A, 19 and 100 in operation at high rates, quite frequent sand removals were necessary, while from Filter No. 1, as before mentioned, sand has not been removed during its last fifteen years of operation up to date. In order to keep the three high-rate filters in operation, that is, open enough to receive and filter their large daily dose of sewage, much more sand per pounds of nitrogen in suspension in the applied sewage had to be removed than from Filter No. 1, operating at a comparatively low rate; the amount of sand removed per hundred pounds of nitrogen in suspension applied being 3.98, 18.90, 15.35 and 9.53 cubic yards, respectively. In other words, the number of pounds of nitrogen in suspension applied, per cubic yards of sand removed, was 25.00, 5.28, 6.51 and 10.10, respectively, for Filters Nos. 1, 14A, 19 and 100. Many other figures are given in the table following in regard to rates of operation and the sand removal necessary to keep these filters operating at their different rates. On the whole, it is noticeable that the removal of suspended organic matter from the strained, clarified and septic sewage was of great help in maintaining high rates with the sand filters receiving sewage treated in these various ways, but that, in order to maintain the rates, even though much of the matter in suspension was removed, more frequent and greater sand removal was necessary. Furthermore, the number of cubic yards removed per hundred pounds of nitrogen in suspension applied was from two and one-half to four and one-half times as great with the high-rate filters as with low-rate Filter No. 1, the chief benefit obtained, of course, being the purification of a large volume of sewage upon a small area. This will be discussed later. Further studies made as regards high rates of operation of sand sewage filters, especially with filters receiving the effluents of trickling filters, — such effluents containing much matter in suspension, — have shown similar results. For instance, Filters Nos. 224 and 249 received the settled effluents of trickling filters, and were operated at rates much higher than the filters just discussed, namely, from 600,000 to 800,000 gallons per acre daily. Following tables show the results as regards quantity of sewage in million gallons per acre daily that could be applied between sand removals, the depth of sand removed, the cubic yards removed per acre and per million gallons filtered, and

the estimated pounds of matter in suspension in the applied sewage per cubic yard of sand removed. Following the results of Filter No. 249, for instance, the amount of sand that it was necessary to remove in order to keep the filter in operation at the high rate desired varied from 2.02 cubic yards to 3.45 cubic yards per million gallons of partially purified sewage applied, and with Filter No. 224 the amount removed varied from 1.49 to 6.10 cubic yards per million gallons filtered. It was especially noticeable, in comparing these two filters that, as the rate maintained was increased, the amount of suspended matter that could accumulate in the sand and still allow this large volume of sewage to pass through the sand decreased rapidly.

Table of Sand Removal Results.

	Filter Number.			
	1.	14A.	19.	100.
	Period of Operation, Jan. 10, '88–Nov. 30, '08.	Period of Operation, June 1, '94–Dec. 31, '99.	Period of Operation, Jan. 28, '90–Mar. 1, '98.	Period of Operation, Jan. 1, '98–Mar. 1, '06.
Total days operated,	6,585	1,747	2,531	3,182
Average rate in thousand gallons per acre daily.	68.30	276.00	162.10	213.30
Million gallons applied per acre,	446.30	479.00	410.30	678.40
Depth of sand removed (inches),	9	13	16	13
Cubic yards sand removed per acre,	1,210	1,748	2,152	1,614
Cubic yards sand removed per million gallons applied.	2.71	3.63	5.24	2.37
Cubic yards sand removed per thousand gross units[1] applied: —				
Total nitrogen,	0.60	0.99	1.46	0.53
Kjeldahl nitrogen,	1.82	4.65	5.33	2.86
Kjeldahl nitrogen in suspension,	3.31	15.20	12.90	7.90
Gross units[1] applied per cubic yard of sand removed: —				
Total nitrogen,	1.67	1.01	0.68	1.91
Kjeldahl nitrogen,	0.55	0.21	0.19	0.35
Kjeldahl nitrogen in suspension,	0.30	0.07	0.08	0.13
Cubic yards sand removed per 100 pounds applied: —				
Total nitrogen,	0.72	1.19	1.76	0.63
Kjeldahl nitrogen,	2.18	5.57	6.36	3.44
Kjeldahl nitrogen in suspension,	3.98	18.90	15.35	9.53
Pounds applied per cubic yard of sand removed: —				
Total nitrogen,	138.90	84.00	56.70	159.50
Kjeldahl nitrogen,	46.00	17.95	15.70	29.00
Kjeldahl nitrogen in suspension,	25.00	5.28	6.51	10.10

[1] Gross units = units × total days operated, or = rate (thousands) × parts × total days operated.

Table showing Per Cent. of Total Organic Nitrogen in Solution and in Suspension in Sewage applied to Filters Nos. 1, 14A, 19 and 100.

Filter No. 1.

Date.	Total Organic Nitrogen (Parts per 100,000).	Per Cent. of Organic Nitrogen.	
		In Solution.	In Suspension.
1888,	1.42	23	77
1889,	1.13	53	47
1890,	1.42	55	45
1891,	1.50	47	53
1892,	1.55	45	55
1893,	1.40	49	51
1894,	1.48	41	59
1895,	1.53	28	72
1896,	1.46	40	60
1897,	1.65	47	53
1898,	1.59	50	50
1899,	1.44	44	56
1900,	1.46	45	55
1901,	1.63	47	53
1902,	1.46	43	57
1903,	1.24	51	49
1904,	1.57	49	51
1905,	1.04	52	48
1906,	1.28	51	49
1907,	1.36	47	53
1908,	0.90	52	48
Average,	1.41	45	55

Filter No. 14A.

Average,	0.78	68	32

Filter No. 19.

Average,	1.00	59	41

Filter No. 100.

Average,	0.83	63	37

Experiments upon Comparative Purification of Fresh and Stale Sewage in Sand Filters.

The change in the character of sewage as it ages has already been described on pages 264–265. In the report for 1894, page 461, an experiment was described illustrating this change. A bottle of fresh sewage was allowed to stand for twenty-four hours in the laboratory. During this period its organic nitrogen (determined by the Kjeldahl process) decreased 51 per cent., the oxygen consumed 24 per cent., and the free ammonia increased over 100 per cent. To determine the differences as regards the disposal of fresh and stale sewage, two small filters were operated from May until the end of October, 1896. To one of these filters fresh sewage, taken directly from the city sewer and brought immediately to the station, was applied, while the other received the stale sewage pumped at the station. The average analyses of the two sewages are given in the following table: —

Average Monthly Analyses of Fresh and Stale Sewage.

[Parts per 100,000.]

	Month.	Free Ammonia.	Organic Nitrogen (Kjeldahl).	Total Nitrogen.	Oxygen Consumed.
Stale sewage,	May,	4.01	1.12	4.41	3.12
Fresh sewage,		2.08	2.30	4.01	6.20
Stale sewage,	June,	3.94	0.93	4.16	2.45
Fresh sewage,		2.23	2.53	4.36	6.20
Stale sewage,	July,	3.86	0.86	4.08	2.65
Fresh sewage,		2.50	2.49	4.54	6.73
Stale sewage,	August,	3.55	0.73	3.64	2.25
Fresh sewage,		2.24	2.36	4.20	6.95
Stale sewage,	September,	3.76	1.02	4.10	2.48
Fresh sewage,		2.10	2.49	4.21	6.65
Stale sewage,	October,	4.20	1.55	4.99	3.84
Fresh sewage,		2.20	2.93	4.73	7.20
Average of stale sewage,	. . . .	3.89	1.04	4.23	2.80
Average of fresh sewage,	. . . .	2.23	2.52	4.35	6.66

The following tables give the monthly analyses of the effluents of these two filters. Filter F received the stale sewage and Filter H the fresh sewage.

Effluent of Filter F (Stale).

[Parts per 100,000.]

1896.	Ammonia.		Nitrogen as —		Total Nitrogen.
	Free.	Albuminoid.	Nitrates.	Nitrites.	
May,	.7137	.0615	1.0500	.0620	1.7980
June,	.1067	.0333	1.4444	.0165	1.6080
July,	.0360	.0204	1.5710	.0015	1.6355
August,	.0130	.0176	1.9250	.0009	1.9654
September,	.0090	.0220	1.9900	.0008	2.0342
October,	.0108	.0285	1.6410	.0007	1.6973
Average,	.1482	.0305	1.6036	.0137	1.7889

Effluent of Filter H (Fresh).

[Parts per 100,000.]

1896.	Free.	Albuminoid.	Nitrates.	Nitrites.	Total Nitrogen.
May,	.2161	.0344	0.8710	.0090	1.1035
June,	.0297	.0275	1.4040	.0074	1.4808
July,	.0145	.0205	1.4140	.0007	1.4601
August,	.0104	.0272	1.3266	.0003	1.3700
September,	.0105	.0250	1.7272	.0002	1.7770
October,	.0284	.0283	1.3720	.0013	1.4438
Average,	.0516	.0272	1.3358	.0031	1.4392

Comparing these results, it will be seen that the total nitrogen applied to the filters was nearly equal, but that 42 per cent. of the nitrogen applied to Filter F was found in the effluent of that filter, while the effluent of Filter H contained only 33 per cent. There was, moreover, in the fresh sewage, on the average, .15 part per 100,000 of nitrogen as nitrates. If this is taken into account, the percentage of nitrogen found in the effluent of Filter H must be reduced to 32. At the end of the experiment, the sand of Filter F, which received the stale sewage, contained about 12 per cent. of the nitrogen applied, while the sand of Filter H, which received the fresh sewage, contained more than twice as much, or 26 per cent. The difference is shown perhaps more clearly by the fact that the upper 3 inches of sand in Filter F contained 38 parts per 100,000 by weight of nitrogen, and the upper 3 inches of sand in Filter H, 78 parts per 100,000. The stale sewage applied to Filter F had 75 per cent. of its nitrogen in the form of free ammonia, while the fresh sewage applied to Filter H had only 42 per cent. of its total nitrogen in this form.

Filtration of Sewage after Varied Preliminary Treatment.

Sand Filtration of Clarified Sewage.

A large group of sand filters has been operated with sewage that has received preliminary treatment. Beginning with Filter No. 32, in 1892, receiving settled sewage, and Filter No. 12, in 1893, receiving the effluents of rapid gravel Filters Nos. 15 and 16, this study of secondary filtration, etc., as an aid to the purification of large volumes of sewage on a limited area, has been continued, and at the present time data can be given showing what quantitative and qualitative results can be expected in filtering sewage that has been (1) clarified by sedimentation; (2) clarified by chemical precipitation; (3) clarified by straining through coke or coal; (4) clarified by septic tank treatment; (5) partially purified by rapid filtration through gravel, coke or broken stone. Discussion of the amounts of organic matter that can be removed by these various methods of treatment is presented in a subsequent portion of this report and figures in regard to sand removal necessary to maintain these rates were given on pages 332–334, inclusive.

Filtration following Sedimentation.

Sewage partially clarified by sedimentation was applied to Filter No. 13A, containing sand of an effective size of 0.19 millimeter, from Sept. 20, 1893, to March 1, 1898, at an average rate for most of this period of 159,000 gallons per acre daily. The following table gives the rate of operation of this filter, together with the average chemical analysis of the applied sewage and the effluent: —

Average Analysis of Sewage after Sedimentation applied to Filter No. 13A.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Ammonia. Albuminoid. In Suspension.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
-	59	-	4.0600	.5100	.3400	.1700	9.73	-	-	3.07	2,408,200

Average Analysis of Effluent of Filter No. 13A.

159,150	56	.17	0.2353	.0348	-	-	9.26	2.85	.0072	0.27	1,391

Filtration following Chemical Precipitation.

Filter No. 19A, containing sand of an effective size of 0.19 millimeter, was operated from Jan. 20, 1893, to Jan. 1, 1898, with superna-

tant sewage after chemical precipitation, at an average rate of 219,000 gallons per acre daily. The following table gives the rate of operation, together with the average analysis of the applied sewage and effluent: —

Average Analysis of Sewage after Chemical Precipitation applied to Filter No. 19A.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Color.	Ammonia. — Free.	Ammonia. — Albuminoid. — Total.	Ammonia. — Albuminoid. — In Solution.	Ammonia. — Albuminoid. — In Suspension.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
-	59	-	3.5100	.3700	.2600	.1100	9.18	-	-	2.26	879,670

Average Analysis of Effluent of Filter No. 19A.

219,330	54	.14	0.4348	.0322	-	-	8.83	2.71	.0195	0.26	2,379

Filtration following Coke Straining.

Filter No. 14A, constructed of 5 feet in depth of sand of an effective size of 0.19 millimeter, was operated with the effluent of the coke strainer from June, 1894, until the end of the year 1899. The average rate for this period was 276,000 gallons per acre daily. The surface sand at the end of operation was somewhat clogged with organic matter and fine coke dust. The following table gives the average analysis of the effluent of this filter during its entire period of operation, together with that of the applied sewage: —

Average Analysis of Sewage, strained through Coke, applied to Filter No. 14A.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Color.	Ammonia. — Free.	Ammonia. — Albuminoid. — Total.	Ammonia. — Albuminoid. — In Solution.	Ammonia. — Albuminoid. — In Suspension.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
-	59	-	3.5000	.3800	.2600	.1200	9.18	-	-	2.20	1,194,400

Average Analysis of Effluent of Filter No. 14A.

276,000	57	.18	0.2499	.0301	-	-	9.76	2.54	.0026	0.29	1,261

FILTRATION OF SEPTIC SEWAGE.[1]

Filters Nos. 100, 116, 118.

Filter No. 100, an intermittent sand filter 1/20000 of an acre in area, constructed of 60 inches in depth of sand of an effective size of 0.26 millimeter, was operated from Jan. 1, 1898, until March, 1908. This filter always received unaerated sewage from Septic Tank A, at rates varying from 63,300 gallons per acre daily during 1908 to 298,400 gallons in 1902, the average rate during its entire period of operation being 199,000 gallons per acre daily. It was able to maintain high rates of operation on account of the removal of suspended organic matter from the sewage in the septic tank, and the finely divided character of the organic matter remaining after passing through the septic tank also aided in maintaining this high rate. Notwithstanding the generally high rate, however, it was necessary at times, when surface clogging occurred and the filter showed evidence of being overworked, to decrease the rate and allow the filter to rest for short periods, in order to obtain a satisfactory effluent. Sand removal was necessary also, so that in 1907, the filter contained but 42 inches in depth of sand; that is to say, 18 inches in depth had been removed in nine years.

Two sand filters, Nos. 116 and 118, were operated also intermittently with septic sewage for three years. Filter No. 116 contained 5 feet in depth of sand of an effective size of 0.17 millimeter, and Filter No. 118 contained 5 feet in depth of sand of an effective size of 0.23 millimeter. This last filter was practically a duplicate of Filter No. 100, and was operated at approximately the same rate. The septic sewage was aerated before application to this filter, however, and for this reason somewhat better results were obtained than from Filter No. 100. The following tables give the rate of operation, together with the average analyses of the sewage applied and of the effluents of these filters during their entire period of operation: —

Average Analysis of Effluent of Septic Tank A applied to Filters Nos. 100, 116 and 118.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Color.	Ammonia.			Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
			Free.	Albuminoid. Total.	Albuminoid. In Solution.		Nitrates.	Nitrites.		
-	59	-	4.5700	.3900	.2700	11.14	-	-	3.12	845,236

[1] See chapter on "Septic Tanks," pages 467–496, inclusive.

Average Analysis of Effluent of Filter No. 100.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
199,573	58	.39	0.7927	.0834	-	10.37	3.17	.0140	0.78	43,384

Average Analysis of Effluent of Filter No. 116.

231,600	56	.20	0.3936	.0349	-	8.59	3.15	.0255	0.36	1,618

Average Analysis of Effluent of Filter No. 118.

217,400	50	.40	0.8759	.0612	-	8.28	2.07	.0346	0.60	10,567

Filtration of Septic Sewage B.

The effluent of Septic Tank B was applied to two filters for a few months during 1900 and 1901. One of these, Filter No. 145, was an intermittent sand filter constructed of 4 feet in depth of sand of an effective size of 0.24 millimeter. The effluent of this filter was never particularly satisfactory, probably on account of the excessive and prolonged septic action carried on in Septic Tank B, due to the period of time that the sewage remained in this tank. The average analysis of the effluent of this filter follows.

Average Analysis of Effluent of Filter No. 145.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
187,500	57	.45	1.6594	.1047	10.12	3.78	.0252	.72	105,900

Double Filtration of Trickling Filter Effluents.

Filter No. 12A.

The effluents of Filters Nos. 15B and 16B[1] — sewage partially strained and partially nitrified — were applied to Filter No. 12A, constructed of 5 feet in depth of sand of an effective size of 0.19 millimeter. This filter gave a highly purified effluent at a rate of nearly 1,000,000 gallons per acre daily for a considerable period, but the clogging that occurred on account of this rate was excessive, and the surface had to be raked and scraped repeatedly to keep it open. The sand also had to be removed and washed from time to time. The stable character of the suspended matter in the effluents applied to this filter was undoubtedly the cause of much of this persistent clogging. The rate had to be reduced occasionally, the average rate during its period of operation of five and one-half years being 629,000 gallons per acre daily. The highest combined rate of this series of three filters taken together was 248,000 gallons per acre daily, from which it fell off to about 200,000 gallons. The following average analysis of the effluent of Filter No. 12A shows that it was of a much better quality than the effluents of the filters just discussed.

Average Analysis of Effluent of Filter No. 12A.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
629,100	56	.19	.0350	.0266	9.54	2.23	.0004	.26	1,441

Filters Nos. 53, 54, 55, 56, 57, 58 and 67.

The effluents of Filters Nos. 51 and 52[1] (see page 368) were applied to three pairs of filters, as follows: Filters Nos. 53 and 54, of sand of an effective size of 0.19 millimeter; Filters Nos. 55 and 56, of sand of an effective size of 0.40 millimeter; and Filters Nos. 57 and 58, of coke breeze. Each of these filters was $\frac{1}{20000}$ of an acre in area, 60 inches deep and operated at a rate of approximately 700,000 gallons per acre daily. Fairly well-purified effluents were obtained from each filter, the best being from Filters Nos. 53 and 54. The coke filters

[1] See chapter on "Trickling Filters," pages 365–388, inclusive.

were operated with the least difficulty. The effluent of Filter No. 66[1] (see page 368) was applied to Filter No. 67, 1/6000 of an acre in area, and constructed of 60 inches in depth of sand of an effective size of 0.19 millimeter. This filter (No. 67), operated at an average rate of 608,000 gallons per acre daily, produced a much better effluent than the filters which received the effluents of Filters Nos. 51 and 52.

Average Analyses of Effluents of Filters Nos. 53, 54, 55, 56, 57, 58 and 67.

[Parts per 100,000.]

Filter Nos.	Quantity Applied. Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
53, ...	698,900	.31	.6177	.0781	12.81	2.0000	.0139	0.49	75,700
54, ...	667,500	.26	.7431	.0572	12.56	1.6900	.0045	0.41	11,300
55, ...	681,400	.45	.8629	.0992	13.01	1.9250	.0215	0.71	145,000
56, ...	694,700	.32	.8600	.0716	12.46	1.7900	.0205	0.49	80,700
57, ...	703,900	.36	.8366	.0768	12.58	1.6453	.0146	0.50	98,200
58, ...	701,900	.30	.6573	.0594	12.22	1.6800	.0096	0.36	89,800
67, ...	608,500	.28	.3181	.0560	12.90	2.7400	.0521	0.46	40,788

NOTE. — Filters Nos. 53, 55 and 57 received the effluent of Filter No. 51, Filters Nos. 54, 56 and 58 received the effluent of Filter No. 52, and Filter No. 67 received the effluent of Filter No. 66. Filters Nos. 53–58, inclusive, were in operation eleven months and Filters Nos. 66 and 67, fourteen months.

Filters Nos. 224, 249 and 250.

These three filters, each 1/20000 of an acre in area, were put into operation for the purpose of studying the refiltration of the effluents of trickling filters more thoroughly than had been done by means of the filters just described. Each received the mixed effluents of Filters Nos. 135 and 136 after these effluents had passed through a sedimentation basin.

Filter No. 224, constructed of 54 inches in depth of sand of an effective size of 0.27 millimeter, was put into operation Oct. 1, 1903, and continued until Nov. 24, 1908, when, on account of severe clogging, it was allowed to rest. It was started at the rate of 1,000,000 gallons per acre daily, but later in the same year this rate was reduced to 600,000 gallons per acre daily, it being intended to operate the filter at this rate as long as possible without disturbing the sand to a greater depth than 3 inches, and to remove sand when the filter failed to take its dose and purify it satisfactorily. The usual surface treatment

[1] Trickling filter.

was followed, and it was found necessary to remove sand several times during its period of operation, as discussed on page 334, the filter, after four years' service, containing but 36 inches in depth of sand. The average rate of operation was 491,000 gallons per acre daily, as shown in the following table.

Filters Nos. 249 and 250, constructed of 60 inches in depth of sand of an effective size of 0.41 millimeter, were first put into operation May 16, 1904, and continued until Oct. 20, 1908. Besides being used as a study of secondary filtration, these two filters were intended also to give information, if possible, in regard to sand removal. Filter No. 249, for example, was never to be dug over to a greater depth than 3 inches, and when this upper 3 inches of sand became so clogged with organic matter that sewage failed to pass, it was to be removed. Filter No. 250, on the other hand, was to be spaded over to a greater depth when necessary, and to be kept in operation as long as possible without removal of sand. At the end of 1907 it was found that there was a total depth of sand of about 40 inches in Filter No. 249, frequent sand removals having been necessary. Its average rate of operation was 655,600 gallons per acre daily. The surface of Filter No. 250 became so clogged from time to time that slight sand removals were necessary, but deep digging of the filter loosened the sand, so that, notwithstanding these removals, the depth of sand in the filter remained practically unchanged, being nearly 60 inches at the end of 1907. The average rate of operation of this filter was 665,900 gallons per acre daily. All these sand filters receiving clarified or partially purified sewage produced satisfactory effluents.

Average Analysis of Effluent of Filter No. 224.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.).	Appearance.		Ammonia.		Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Turbidity.	Color.	Free.	Albuminoid.		Nitrates.	Nitrites.		
491,000	57	0.1	.30	.1904	.0519	11.28	2.86	.0040	.57	35,940

Average Analysis of Effluent of Filter No. 249.

655,600	59	0.3	.36	.2743	.0607	12.20	3.33	.0067	.62	29,920

Average Analysis of Effluent of Filter No. 250.

665,900	59	0.4	.34	.2183	.0609	12.04	3.36	.0144	.60	46,200

Coagulation and Mechanical Filtration of Effluents of Sprinkling Filters.

Sand Filter No. 300.

Studies upon mechanical filtration of the effluents of trickling filters were made during 1906 and 1907. The settled effluents from trickling filters Nos. 135, 136, 233, 235, 247 and 248 were mixed in a storage basin, passed thence through an outlet pipe to the bottom of a coagulation and sedimentation tank, where chemicals were added, then passed upward and overflowed upon a sand filter, No. 300, $\frac{1}{80000}$ of an acre in area, and started April 20, 1906. The rate of filtration and the depth of water in the filter were regulated automatically. This was a mechanical filter, and when it became clogged to such an extent that water would not pass through at the prescribed rate, the filtering material was washed by passing a strong upward current of clear water through the sand, which was at the same time thoroughly agitated. At the beginning the filter contained 24 inches in depth of washed sand having an effective size of 0.71 millimeter, and was operated at a rate of approximately 50,000,000 gallons per acre daily, the applied partially purified effluent first being treated with sulphate of alumina in amounts varying between 1.3 and 3.5 grains per gallon.

On May 20 the sand in the filter was removed and replaced by 24 inches in depth of beach sand, having an effective size of 0.35 millimeter, following which the filter was operated until August 19 at a rate of 50,000,000 gallons per acre daily. On August 20 the rate was reduced to 25,000,000 gallons per acre daily, at which rate the filter was operated during the remainder of the year.

From May 20, when the filtering material was changed, until August 25, the coagulants employed were copperas and lime in varying amounts. On August 25 samples of a new form of ferrous sulphate, called "sugar sulphate of iron," stated to contain less water of crystallization and more available iron than commercial copperas, and of a similar iron sulphate with which was incorporated a small amount of copper sulphate, were obtained, and thereafter were used as coagulants during alternate weeks until the end of the year.

Analyses of the various coagulants showed that the commercial copperas contained about 55 per cent. available $FeSO_4$, the sugar sulphate of iron about 64 per cent. available $FeSO_4$, the copper iron sulphate about 63 per cent. available $FeSO_4$ and .2 per cent. of copper, equivalent to about ½ per cent. of $CuSO_4$, and the sulphate of alumina contained about 58 per cent. available $Al_2(SO_4)_3$.

In large quantities commercial copperas and sugar sulphate of iron cost $10.00 per ton; copper iron sulphate costs about $11.00 per ton; lime costs about $6.00 per ton; sulphate of alumina costs $20.00 per ton, and these values have been used in computing the costs of treatment.

The coagulation and sedimentation tank was of such capacity that the period between the addition of coagulants and the time the water reached the filtering material was about two and one-half hours when the filter was operated at a 50,000,000-gallon rate, and about five hours when the filter was operated at a 25,000,000-gallon rate.

An average of twelve determinations of the volume of wash water showed that about 6 per cent. of the total volume filtered was required for washing.

The results of chemical analyses indicated that the purification was entirely mechanical, and that no biological action occurred in the filter, as is shown by the fact that the amounts of free ammonia, nitrates and nitrites were practically unchanged.

With sulphate of alumina as a coagulant, no lime or soda ash was required, and an adequate removal of suspended matter was accomplished by the use of from 2.5 to 3.5 grains per gallon. Eighty-three per cent. of the total number of bacteria and 92 per cent. of B. coli were eliminated when 3.5 grains were used, at a cost of about $5.00 per million gallons for chemicals. During this period the filtering material was much coarser than was the case later on.

With commercial copperas, without lime, there was no removal of color or turbidity, and very little elimination of bacteria, even when amounts as large as 8.7 grains per gallon were used. This was undoubtedly due to the fact that while the raw water was sufficiently alkaline to more than compensate for the copperas added, the presence of considerable free and half-bound carbonic acid prevented the reaction from taking place.

When commercial copperas and lime were added, the purification was much more satisfactory, from 90 to 100 per cent. of the turbidity and from 40 to 60 per cent. of the total albuminoid ammonia being removed. The removal of bacteria was less satisfactory, being at all times less than 90 per cent. About 8.5 grains of copperas and about 4 grains of lime per gallon were used during this period, at a cost of about $7.90 per million gallons.

From August 21 to 24, with 8.5 grains of copperas and 6.0 grains of lime, at a cost of $9.12 per million gallons, and with the filter in operation at the comparatively low rate of 25,000,000 gallons per acre daily, the removal of color, turbidity and albuminoid ammonia was satis-

factory, and the removal of bacteria and of B. coli was 98.1 and 99.6 per cent., respectively.

When the raw water received "sugar sulphate of iron" and lime in the proportion of about 8.0 and 9.0 grains, respectively, the removal of turbidity was complete, the removal of color varied from 56 to 65 per cent., the removal of albuminoid ammonia was between 54 and 68 per cent., and the removal of bacteria and of B. coli was about 99 per cent.

When the copper iron sulphate was used the removal of color and albuminoid ammonia was slightly greater than when the sugar sulphate was used, and the removal of B. coli was practically the same; but the removal of turbidity and of total bacteria was less satisfactory. The cost of treatment with sugar sulphate of iron and lime was about $9.65 per million gallons, this cost being increased slightly when the copper salt was used.

During the first five months of 1907 the average rate of operation was 50,000,000 gallons per acre daily, and the effluents were applied after treatment with copperas and lime and sedimentation for about two and one-half hours. About 8 grains of copperas and 10 grains of lime per gallon of water filtered were required to produce a clear effluent, and it was necessary to wash the filter at intervals of about four hours. The average quantity of water filtered between washings was only about 10,000,000 gallons per acre daily. The cost of chemicals was about $10.30 per million gallons.

The experiments indicated clearly that satisfactory removal of color, turbidity and a considerable portion of the organic matter may be accomplished by coagulation with sulphate of alumina, or with one of the three forms of ferrous sulphate mentioned combined with lime, this to be followed by filtration at rates of 25,000,000 gallons per day or somewhat higher in filters of the mechanical type. The removal of from 90 to 99 per cent. of the bacteria occurred only when the removal of suspended matter was practically complete.

The numbers of bacteria in the effluent were never less than 1,000 per cubic centimeter and rarely less than 10,000 per cubic centimeter during any portion of the experiments, while the numbers of B. coli were at all times as large or larger than in the very polluted Merrimack River water.

The cost of coagulants necessary to produce an effluent free from suspended matter was so large when iron salts and lime were used and the volume of water filtered between washings was so small as to make the process apparently impracticable. The results obtained during the early portion of the experiments indicated, however, that clarification

might be produced at less cost with sulphate of alumina than with either of the iron salts tested, for the reason that much larger amounts of the cheaper iron salts must be used; they require furthermore the addition of lime.

In the following tables are shown various data regarding the operation and work of the filter, the results being grouped according to the rate of filtration and the kind of coagulants used.

Average Chemical Analyses of Effluents from Trickling Filters applied to Filter No. 300, and Effluent from Filter No. 300.

Settled Trickling Filter Effluents applied to Filter No. 300.

[Parts per 100,000.]

Period.	Rate, Million Gallons per Acre Daily.	Temperature (Deg. F.).	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Iron.	Free Carbonic Acid.
Apr. 20, 1906–May 19, 1906,	-	65	.65	2.1700	.2250	.1487	12.77	1.09	.1056	1.21	0.2750	12.9
May 20, 1906–Aug. 24, 1906,	-	68	.60	1.6337	.1375	.0973	15.16	1.66	.0513	0.97	0.1882	8.1
Aug. 25, 1906–Nov. 30, 1906,	-	62	.72	2.8695	.2276	.1706	15.46	0.65	.0560	1.59	0.3690	3.2
Dec. 1, 1906–Apr. 30, 1907,	-	57	.81	3.7635	.3247	.2118	12.65	0.35	.0269	2.40	0.6596	3.3

Effluent from Filter No. 300.

Period.	Rate, Million Gallons per Acre Daily.	Temperature (Deg. F.).	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Iron.	Free Carbonic Acid.
Apr. 20, 1906–May 19, 1906,	50	62	.63	1.9012	.1277	-	11.70	0.91	.1142	0.76	1.4500	9.8
May 20, 1906–Aug. 24, 1906,	50	68	.67	1.6374	.0780	-	13.25	1.12	.0665	0.47	0.6076	7.9
Aug. 25, 1906–Nov. 30, 1906,	25	62	.27	2.3962	.0785	-	12.08	0.18	.0394	0.57	0.0412	3.1–
Dec. 1, 1906–Apr. 30, 1907,	50	55	.59	3.7109	.1355	-	11.18	0.05	.0558	0.93	0.1390	0.3–

Average of Bacterial Analyses.—Filter No. 300.

Period.	Average Bacteria per Cubic Centimeter. Applied Effluents.	Average Bacteria per Cubic Centimeter. Effluent from Coagulation Basin.	Average Bacteria per Cubic Centimeter. Effluent from Filter.	Average B. Coli per Cubic Centimeter. Applied Effluents.	Average B. Coli per Cubic Centimeter. Effluent from Coagulation Basin.	Average B. Coli per Cubic Centimeter. Effluent from Filter.
Apr. 20, 1906–May 19, 1906, .	1,135,300	1,402,200	975,000	8,600	3,700	16,500
May 20, 1906–Aug. 24, 1906, .	380,100	333,200	172,900	55,300	16,500	34,600
Aug. 25, 1906–Nov. 30, 1906, .	583,500	158,400	82,500	50,700	2,400	730
Dec. 1, 1906–Apr. 30, 1907, .	650,000	135,000	73,300	15,600	4,500	730

Average Removal of Bacteria and Organic Matter. — Filter No. 300.

Period.	Per Cent. of Bacteria removed by —			Per Cent. of B. Coli removed by —			Per Cent. of Albuminoid Ammonia removed.
	Coagulation and Sedimentation.	Filter.	System.	Coagulation and Sedimentation.	Filter.	System.	
Apr. 20, 1906-May 19, 1906,	0.0	30.5	14.5	57.0	0.0	0.0	43.2
May 20, 1906-Aug. 24, 1906,	12.2	48.1	54.4	70.2	0.0	37.4	43.5
Aug. 25, 1906-Nov. 30, 1906,	70.4	47.8	84.6	95.3	69.6	98.6	65.6
Dec. 1, 1906-Apr. 30, 1907,	79.2	45.9	88.8	71.1	83.8	95.3	58.2

Conclusions. — Sand Filtration of Sewage.

The efficiency and permanence of sand filters have been demonstrated so well in Massachusetts by the past twenty years' work of these experimental filters and the municipal filters in operation at many cities and towns that little need be said as a summary other than the facts already given. The filters at the station have been operated more carefully and the essential facts of their operation and results more fully recorded, however, than could have been possibly the case at any of the municipal filters; the results obtained from them, therefore, are of especial value. It is of interest to know that the principal sand filters, started late in 1887 or early in 1888, from the coarsest to the finest, have been kept in successful operation without undue clogging, and that removal of clogged surface sand has not been necessary during the past sixteen years. It is also important to note that the effluents of these filters during 1908 were considerably better than the average maintained during the entire period of twenty-one years, and approximated in purity the effluents obtained when the filters were first put into operation.

The essential facts in regard to the working of sand filters have been given in previous pages. Some of them may be summarized, however, as follows: (1) better effluents can be obtained by sand filtration of sewage than by any other method of sewage treatment; (2) rates of filtration must be low compared with the rates that can be maintained with contact and trickling filters, as described later in this report; (3) with sewage as strong as that at Lawrence — probably stronger than average American sewage — it is inadvisable to undertake to operate the best sand filter at a rate exceeding 75,000 gallons per acre daily, and with fine sands the rate must be much less; that is, these rates cannot be exceeded if absolute permanence of the filter area is desired; (4)

sand filters properly cared for and not overworked are practically permanent; (5) sand removal is at times necessary, especially if systematic care is not given to the filters, and if the rate of application and the quality or strength of the sewage overloads the filter, in other words, if the rate maintained causes the application of a greater body of organic matter than the biological life of the filter can adequately care for; (6) a certain portion of the suspended organic matter in sewage retained by sand filters is stable, and resists for long periods changes due to chemical and biological forces, — it is practically as stable as the organic matter of soil; (7) the rate of filtration should be proportioned to the strength of the sewage, as shown by the organic matter contained in a given volume of water and especially the organic matter in suspension; (8) when the rate of application of sewage goes beyond a certain normal point, sand removal becomes necessary. Furthermore, the amount of sand that must be removed increases more rapidly than the rate, as shown by the figures on page 334; (9) preliminary treatment of sewage as previously described allows sand filters to be operated more or less satisfactorily at rates much greater than is possible with untreated sewage, as instanced by the results obtained with Filters Nos. 13A, 19A, 14A, 100, 12A, 53, 54, 55, 56, 57, 58, 224, 249, 250, etc., on pages 338–344, inclusive.

Period of Time elapsing before Nitrification occurs in Different Classes of Filters.

In the special report upon purification of sewage and water (1890) the description of the process of nitrification and the influence of various substances and conditions upon it form a very prominent feature. In the report for 1894 a discussion was presented in relation to the time elapsing previous to nitrification in practically every filter operated up to that date; and a table was given showing the number of days elapsing after sewage was applied, before nitrates appeared in the effluent of each filter. (See page 475, report for 1894.) In this table it was considered that nitrification had really begun when the amount present in the effluents reached 0.10 part per 100,000, and was steadily increasing. A large part of this table is reproduced here, together with results of a similar kind with a few of the filters, especially of the trickling and contact variety operated since 1894. In addition, moreover, figures are given showing the time elapsing before the nitrates in the effluents of these trickling and contact filters reached 1.0 part per 100,000.

Intermittent Filters.

Filter Nos.	Effective Size (Millimeter).	Date when Sewage was First Applied.	Quantity Applied. — Gallons per Acre Daily.	Number of Days before Nitrates averaged — 0.1[1]	1.0[1]
1, ...	0.48	Jan. 10, 1888,	47,000	84	423
2, ...	0.08	Dec. 19, 1887,	52,000	155	534
4, ...	0.04	Dec. 19, 1887,	47,000	134	688
6, ...	0.35	Jan. 12, 1888,	38,000	110	126
9A, ...	0.17	Nov. 18, 1890,	120,000	108	158
11, ...	0.35	Feb. 8, 1888,	30,000	67	90
12, ...	0.48	Feb. 16, 1888,	30,000	63	80
12A, ...	0.19	July 25, 1892,	320,000	4	14
13A, ...	0.19	Sept. 27, 1893,	360,000	10	84
14, ...	0.48	Feb. 29, 1888,	140,000	32	60
100, ...	0.26	Jan. 1, 1898,	100,000	31	45
116, ...	0.17	Sept. 24, 1898,	100,000	11	18
118, ...	0.23	Nov. 16, 1898,	100,000	7	43
140, ...	0.11	June 7, 1900,	50,000	8	8
141, ...	0.11	June 7, 1900,	50,000	8	8
305, ...	0.25	Aug. 24, 1906,	60,000	7	21
306, ...	0.25	Aug. 24, 1906,	60,000	7	21
312, ...	0.25	Oct. 1, 1906,	50,000	4	18
313, ...	0.25	Oct. 1, 1906,	100,000	18	32
314, ...	0.25	Oct. 1, 1906,	150,000.	18	32
Trickling Filters.					
15B, ...	5.10	July 25, 1892,	160,000	12	12
15C, ...	5.10	Feb. 26, 1894,	480,000	53	65
16B, ...	5.10	July 25, 1892,	160,000	13	35
82, ...	Cinders.	April 12, 1897,	484,000	22	36
117, ...	Stone.	May 22, 1899,	1,877,000	9	9
131, ...	Coke.	Sept. 26, 1899,	2,046,000	24	36
233, ...	Clinker.	Jan. 1, 1904,	981,600	39	68
235, ...	Clinker.	Jan. 1, 1904,	1,020,800	25	39
247, ...	Stone.	May 16, 1904,	967,900	23	242
248, ...	Stone.	May 16, 1904,	1,000,000	22	158

[1] Parts per 100,000.

Contact Filters.

Filter Nos.	Effective Size (Millimeter).	Date when Sewage was First Applied.	Quantity Applied. — Gallons per Acre Daily.	Number of Days before Nitrates averaged — 0.1[1]	1.0[1]
21A,	1.60	March 19, 1894,	480,000	55	121
108,	Coke.	March 1, 1898,	817,300	45	71
175,	Coke.	June 3, 1901,	930,000	20	65
176,	Coke.	June 3, 1901,	907,500	20	127
221,	Stone.	July 7, 1903,	572,700	21	85
251,	Coke.	Aug. 1, 1904,	1,000,000	18	155

[1] Parts per 100,000.

Studies of the Effect of Various Substances upon Nitrification, including Albumen, Peptone, Ammonium Chloride and Sodium Carbonate, Sulphuric Acid, Saltpeter, Common Salt, Sugar, Soap, Urine, Free Oxygen, Phenol, Mercuric Chloride, Formalin, Arsenic, Naphthalene, Sulphides, Bleaching Powder and Copper Sulphate.

Many experiments have been made at the station to determine the effect upon nitrification of an excess of a number of substances, which substances may either occur naturally in sewage or may, at times, find their way into it. With the exception of certain experiments with chlorine in the form of bleaching powder, made during 1908, all of these investigations have been made with intermittent filters. A large proportion of the studies were made during the first four years of the station's existence, and were described in detail in the reports for 1890 and 1891. Experiments with urine were made in 1897; with phenol, mercuric chloride and formalin in 1902, and were described in detail in the reports for those years. The studies on the effect of arsenic and of bleaching powder were made during 1907 and 1908 and are detailed here for the first time. A description of some of the filters used in the various experiments, with the exception of the new filters operated with sewage containing arsenic, will be found elsewhere in this report. As far as space will permit, the results of the various experiments are here given in the words of the original reports, to which page references are appended.

Nitrification of Peptone.

On March 9 [1889], instead of sewage, a solution of peptone consisting of 3 gallons of city water, in which was dissolved so much peptone that the solution had 1 part per 100,000 of albuminoid ammonia, was applied to Filter No. 11. This peptone is an albuminoid compound which is soluble in water, and decomposes readily and completely. . . . When the peptone

was first dissolved in the water, the ammonia was nearly all in the form of albuminoid ammonia, but this so readily changed to free ammonia, that, in making an analysis immediately after dissolving the peptone, the free ammonia amounted to about 0.17 part; and at any subsequent time this amount of free ammonia would be found to be very much increased.

The general results of the application of peptone are as follows: the nitrates increased from 0.2500 part to 1.0000 part at the end of March; the free ammonia decreased in the same time to 0.0028 part, and the albuminoid ammonia to 0.0166 part.

The total nitrogen found in the effluent in April was 80 per cent. of that applied; in May, 87 per cent.; and in June it was equal to the amount applied. — Special report for 1890, pp. 498, 499.

Nitrification of Albumen.

From April 16 to June 20, 1889, instead of sewage there was applied daily to tank No. 12, 1½ gallons of city water, into which had been stirred a sufficient amount of baked and pulverized egg albumen to supply to the mixture 2.8 parts of nitrogen per 100,000 parts.

Albuminoid ammonia is so named because it is ammonia that may be obtained from organic substances by the same method of analysis as that by which ammonia may be obtained from egg albumen; hence, egg albumen may be regarded as the substance typical of albuminoid ammonia.

Within two weeks from the time of the first application the nitrates of the effluent became 1.7 parts per 100,000, and this continued to be the amount of the nitrates during the following two months. It would appear from these results that this insoluble nitrogenous matter is converted into nitrates in the proportion of 61 per cent. of the nitrogen contained in the albumen applied. — Special report for 1890, pp. 132, 133.

From July 10 to August 7 there was applied city water containing blood albumen sufficient to supply 1.4 parts of nitrogen per 100,000. When it was first applied the nitrates were decreasing, and they continued to fall for ten days, after which time the nitrates remained nearly constant for two weeks, and averaged 1.3 parts, which is 91 per cent. of the nitrogen applied.

Comparing the results obtained with sewage it is probable that but little was stored, for the percentage which the nitrogen of the nitrates was of the applied nitrogen is but little below that found with sewage when no nitrogen was being stored. — Special report for 1890, pp. 132–134.

Capacity of a Filter to nitrify Ammonia.

For nearly a year Tank No. 13 had been filtering sewage at the rate of 60,000 gallons per acre daily. Commencing Jan. 14, 1889, at which time it was giving a perfectly nitrified effluent, a solution of ammonium

chloride in city water containing 1 part ammonia per 100,000 was substituted for the sewage. With this solution there was mixed just enough sodium carbonate to combine with the chlorine of the ammonium chloride, and also with the nitric acid equivalent to the ammonia. The strength of the solution applied was increased from time to time until it contained 34 parts ammonia. It was always found that, after increasing the dose, complete nitrification was not at once obtained, but the effluent contained ammonia and nitrites for a time. The ammonia first disappears from the effluent, and the nitrites soon follow, with increased development of nitrates. On July 10, the dose, which had been applied in 3 gallons of water, was applied in 1½ gallons, so that it contained 68 parts ammonia. While applying this strong solution, containing many times as much ammonia as is found in the strongest sewage, a nearly complete nitrification was obtained. — Special report for 1890, p. 727.

Effect of Excess or Deficiency of Alkali.

In 1889 Filter No. 13 received a solution of ammonium chloride and sodium carbonate, as described previously. During July an excess of sodium carbonate was added to the dose for this filter.

This did not in the least interfere with the nitrification. The excess of sodium carbonate passed through without change, and increased the alkalinity of the effluent. In October an insufficient quantity of sodium carbonate was added with the ammonium chloride. The first result of this reduction was to cause an almost total stoppage of nitrification. After a little time, however, nitrification began again, but did not become complete, as, indeed, it could not without the presence of free nitric acid in the effluent. This was not the case, for the effluent was always alkaline. An unexpected result of this treatment was the production of an enormous quantity of nitrites. At times more than one-half of the total nitrogen was in this form. It is not easy to see how lack of base could produce this result, for nitrogen as nitrous acid requires as much alkali for its neutralization as nitrogen as nitric acid. — Special report for 1890, p. 728.

These experiments with Filter No. 13 were continued through 1891 and 1892, and similar ones were made with Filters Nos. 11 and 12 in the same years. As a result the facts noted above were confirmed. (Report for 1891, pp. 534–539, report for 1892, p. 438.)

In 1890, when these statements were made, practically nothing was known of the behavior of acids and bases in dilute solution. Studies made in 1904, when this subject was better understood, explain the early results and throw a somewhat different light upon the effect of a deficiency of alkali upon nitrification.

The results obtained by the two indicators (methyl orange and gallein) were practically the same, indicating the absence of organic acids from the

effluents tested. The determinations made upon the effluents of filters in operation at the station show clearly that when the most complete purification and the highest nitrification are occurring in these filters, their effluents are either acid or only slightly alkaline, and that the poorer the nitrification the greater is the degree of alkalinity of the effluents. — Report for 1904, p. 227.

The acidity is due to free nitric and hydrochloric acids, and the hydrochloric acid is probably liberated from the sodium chloride by free nitric acid. Theoretically, if dilute nitric acid is added to a dilute solution of sodium chloride, the sodium chloride gives up a part of its base to the nitric acid, so that there will be equivalent amounts of each acid free in solution. — Report for 1904, p. 230.

This also is true concerning nitrous or any other acid.

Effect of Acid.

In October, 1889, Tank 15A was in good nitrifying condition. Commencing October 22 sulphuric acid equal to 22.5 parts per 100,000 was added to the sewage. The result of making the sewage acid was a great increase in free ammonia and a decrease of nitrates in the effluent. The nitrates and nitrites have not, however, completely disappeared after several months, although the entire mass of the gravel of the tank must be acid. The actual degree of acidity of the effluent agrees closely with the amount calculated from the quantity of acid added to the sewage. The amount of nitrates is about one-tenth as much as would be formed if no acid was added. Nitrites are also present in the effluent. — Special report for 1890, p. 728.

The experiments with acid sewage were continued until 1894, and the above conclusions were confirmed. It was learned, however, that by mixing a small proportion of marble chips with the filter material, the excess of acid would be neutralized and a satisfactory nitrification obtained. (See report for 1891, p. 563; also reports for 1892, 1893 and 1894.)

Effect of Nitrates.

For five days saltpeter was dissolved in the sewage (applied to Filter No. 15A) in sufficient quantity to give 72 parts of nitrogen per 100,000. In two days the nitrates increased to 27 parts per 100,000, and on the third and fourth days were 64 parts per 100,000. This saltpeter was discontinued after the fifth day, and twelve days after the first was applied the nitrates had fallen to 15 parts per 100,000. — Special report for 1890, p. 552.

Effect of Common Salt.

Tank No. 11 had been used for sewage filtration and for experiments with peptone. Commencing July 2 a solution in city water, of ammonium chloride with a suitable amount of sodium carbonate, was added. After a

month the tank was in good order, and the effluent contained about as much nitrogen as the charge. On August 8 common salt was added to the charge in such quantities that it contained 1,200 parts chlorine per 100,000. Nitrification was checked, and the solution came through almost unchanged. On August 27 the addition of salt was suspended. During the time that the salt water was being washed out of the tank large amounts of nitrites were formed.

On September 9 nitrification was again complete. Salt was again added to the charge, but in much smaller quantity than before. The amount added remained constant until September 25, when a little more was added, and on each succeeding day the amount was slightly increased, until in January, 1899, the solution was nearly saturated. With a gradually increasing dose nitrification continued, with more salt than was sufficient to stop it when first applied. It has been noticed that, with incomplete nitrification in presence of salt, large amounts of nitrites are produced. — Special report for 1890, p. 729.

Effect of Sugar.

Tank No. 12 had been used for the filtration of sewage, egg albumen and city water. Commencing Oct. 23, 1889, there was applied to it a solution of granulated sugar in city water containing 100 parts per 100,000. The effect of this was to stop nitrification. From the first the greater part of the sugar came through apparently unchanged, and after six weeks the effluent contained three-fourths of the applied sugar. Beginning December 9, 3 gallons of sewage were applied daily, without any sugar. Nitrification was resumed at once, and became nearly complete.

Commencing January 1, 10 parts of granulated sugar were dissolved in the sewage, and on the 13th the amount was increased to 20 parts. The effect of this was to slowly reduce the amount of nitrates in the effluent, without any increase of ammonias. In February the nitrates increased rapidly and the effluent contained no sugar, or at least less than 1 per cent. of the amount applied. It will be noticed that in the first case the sugar was added in solution in city water; in the latter it was dissolved in sewage. — Special report for 1890, p. 730.

Effect of Soap.

In 1890 a solution of soap containing 90 parts per 100,000 was applied to Filter No. 12, this amount being subsequently increased to 440 parts. The effect was to stop nitrification, but with the smaller amount a good purification was obtained. With the larger amount of soap the filter quickly became clogged. Attempts were made with little success to relieve this clogging by resting, by washing with city water and by the application of lime and of caustic potash.

This experiment has shown that soap is capable of completely clogging sand, thereby rendering it unfit for sewage purification. At the same time

it must be borne in mind that the solution of soap applied contained many times as much fatty acids as is usually carried by the sewage received at the experiment station, the total quantity of soap applied being equivalent to 30 tons of soap an acre. The clogging was mainly near the surface. — Report for 1891, pp. 535, 536.

Effect of Urine.

In 1897 experiments were made to determine how great a proportion of the sewage could be composed of urine and still be purified by the action of nitrification. Two filters, Nos. 83 and 84, containing sand and coal ashes, respectively, were put into operation in May, and to each was applied a mixture of 3 parts sewage and 1 part urine at a rate of 200,000 gallons per acre daily. Nitrification did not become established in either filter during the first four months of operation, although the rates of operation were reduced and the proportion of urine was varied from time to time. During the latter part of August, after the rates had been reduced to about 20,000 gallons per acre, the nitrites in the effluents from both filters began to increase rapidly. At this time the applied sewage was composed of equal parts sewage and urine, with a small proportion of hay infusion. In September the nitrates in the sand filter effluent increased to about 3.0 parts, and although there was no appreciable amount of nitrates in the effluent from the cinder filter, the nitrites increased to about 22 parts per 100,000. In October the nitrates in the effluent from the sand filter averaged about 38 parts and the nitrites about 33 parts. The nitrites in the effluent from the cinder filter continued very high in September, October and November, but the nitrates never increased above 2 parts. With the advent of cold weather nitrification was checked in both filters, and the experiment was discontinued. It is evident that the quantity of organic matter applied to these filters at the start was greatly in excess of the amount they could dispose of, and that had a smaller rate been maintained at first, nitrification would probably have become established sooner, higher rates could have been maintained possibly, or a greater proportion of urine could have been treated successfully. The experiment shows, however, that any proportion of urine ever likely to be found in a sewage would not prohibit the purification of that sewage by intermittent filtration. (Report for 1897, p. 452.)

Effect of the Amount of Free Oxygen upon Nitrification.

All of the experiments thus far described have been made with filters of such open material that there is an abundance of oxygen in every part. With continuous filtration there is no nitrification, and there is reason to

believe that this is due to the lack of oxygen. Still, the movement of the liquid through the sand is different in continuous and intermittent filtration, and it was desirable to make experiments in which the conditions of descent of sewage should be exactly like those of intermittent filtration, but from which all oxygen should be excluded. It was also desired to find the minimum amount of oxygen which would support nitrification. For these experiments Tank No. 14 was used.

The bottom of the tank was trapped, and a cover put on the top, attached to the tank by a mercury seal, which made it air tight. Sewage was put in through a large funnel with a stop-cock, so that no air was admitted, and a perforated plate distributed it over the surface. The effluent was free to pass the trap at the bottom, but no air could get back into the tank.

In a week nitrification had stopped and the effluent was little better than sewage.

This experiment was repeated a number of times with the same result, nitrification being established between the successive trials by forced aeration of the filter. The aspirator was then so arranged that air was drawn from the bottom of the filter and returned to the surface, a small amount of fresh air being admitted from time to time in order that the oxygen should not be entirely exhausted. In these experiments it was found that nitrification was as complete when the oxygen content of the air in the filter was as low as 1 to 3 per cent. as when a larger quantity was present, provided a constant circulation of air was maintained throughout the material. (Special report for 1890, pp. 730, 731.)

Effect of Phenol, Mercuric Chloride and Formalin.

In connection with an application to the Board in regard to the purification of hospital sewage containing disinfectants, three sand filters, Nos. 182, 183 and 184, were started Oct. 28, 1902, and were operated at rates of about 50,000 gallons per acre daily with sewage containing phenol, mercuric chloride and formalin, respectively. No germicides were applied until December 16, when the filters had reached a condition of good nitrification. Phenol was first applied to Filter No. 182 in the proportion of 1 part in 200 parts of sewage. Nitrification was quickly destroyed and the effluent of the filter became sterile. The proportion of phenol was reduced from time to time, but not until the amount added was as low as 1 part in 2,667 parts of sewage did nitrification become re-established. The amount of phenol was then gradually increased until the filter was maintaining good nitrification while receiving phenol in the proportion of 1 part in 1,000. During the period when the phenol was being gradually increased nitrification was temporarily checked a number of times, but again became established with-

out decreasing the amount of disinfectant. With an increase in phenol to 1 part in 750 nitrification fell off somewhat, and with a further increase to 1 part in 500 it was completely destroyed, and could not again be established until the amount of phenol was considerably reduced.

Mercuric chloride was first added to Filter No. 183 in the proportion of 1 part in 10,000. This proportion was gradually increased without effect upon nitrification until the filter was receiving the disinfectant in the proportion of 1 part in 750 parts of sewage. A further increase to 1 part in 500 checked nitrification, which did not again become active until the proportion of mercuric chloride was reduced to 1 part in 2,000. After nitrification had been re-established the mercuric chloride was again gradually increased, until the filter was receiving 1 part in 500 without ill effects. The mercuric chloride was then increased to 1 part in 350, and good nitrification continued, although the nitrates in the effluent were not as high as during the preceding period. A further increase to 1 part in 250 effectually checked nitrification.

Formalin was applied to Filter No. 184 in the proportion of 1 part in 2,000. It was gradually increased to 1 part in 250 without ill effects, but a further increase to 1 part in 150 effectually checked nitrification. The formalin was then reduced until nitrification was re-established and the proportion gradually increased, but an amount greater than 1 part in 250 caused a check in nitrification. (The details of experiments with these filters are given on page 221 of the report for 1902.)

Effect of Arsenic.

In connection with studies on the purification of tannery wastes containing arsenic, it was desirable to determine how much arsenic might be present in a sewage without seriously interfering with its purification by filtration, and whether the proportion of arsenic ordinarily present in such wastes would prevent the starting of nitrification in a new filter.

On Jan. 20, 1908, two filters, containing 3½ feet in depth of sand of an effective size of 0.25 millimeter, were started to determine the effect of small proportions of arsenic upon the starting of nitrification. Settled sewage was applied to these filters at a rate of 100,000 gallons per acre daily, arsenic in the proportion of 0.15 part per 100,000 being applied to Filter No. 337, and none being applied to Filter No. 338. Nitrification became established in the filter receiving arsenic in four weeks and in the filter which did not receive arsenic, in seven weeks. On May 22, 1908, the above experiment was repeated with two new filters, Nos. 344 and 345, arsenic in the proportion of 25 parts per 100,000 being mixed with the sewage applied to the latter, while settled sewage without arsenic

was applied to the former. At the end of two weeks the effluent of the filter receiving arsenic contained 2.3 parts nitrates, while the nitrates in the effluent of the filter receiving no arsenic amounted to only about 0.4 part. At the end of the third week the nitrates in the effluent of the filter receiving arsenic had increased to 5.2 parts and in the effluent of the other filter to 1.0 part. At the end of the fourth week nitrification was equally active in both filters. The arsenic in the tannery sewage averaged about 15 parts per 100,000. From these two experiments it is evident that arsenic in the amounts used would have no ill effect upon the starting of nitrification in new intermittent filters. It may have been only a coincidence that nitrification first started in the filters to which arsenic was applied.

Beginning Nov. 25, 1907, settled sewage containing arsenic in the proportion of 0.01 part per 100,000 was applied to Filter No. 242, which had been operated for several years with septic sewage, and which was giving a well-nitrified effluent. This filter was now called No. 335. The amount of arsenic was gradually increased each week, until on June 12 it had reached 50 parts per 100,000. With the arsenic increased slowly in this manner there was no decrease in nitrification, and the filter continued to purify the sewage without trouble.

Beginning March 10, 1908, arsenic was applied to Filter No. 100, which had been operated for ten years with septic sewage, the filter being now called No. 342. The upper layers of the sand in this filter were badly clogged, and the rate of 65,000 gallons per day at which the filter was operated was very close to the maximum which could be maintained without loss in nitrification. Arsenic was applied at first in the proportion of 6 parts per 100,000, and on March 21 this was increased to 24 parts. By the end of April the filter had become overworked and nitrification ceased. The filter was then dug over and rested for one week, and sewage without arsenic applied for two weeks, until nitrification had again become active. The arsenic was then reapplied, and about four weeks later was increased to 48 parts. Nitrification was not affected and the filter continued to purify the sewage without trouble.

Beginning June 25 the arsenic applied to Filter No. 345, which had received sewage containing this germicide from the time it was first started, was gradually increased, until by the middle of September it was receiving sewage containing 400 parts arsenic, without any decrease in nitrification having occurred. A further increase in the arsenic to 500 parts per 100,000, however, effectually checked nitrification, and it could not be again re-established, even though the arsenic was omitted from the sewage.

In all of these experiments the arsenic was applied to the filters for

convenience as As_2O_3, dissolved in sodium carbonate and made nearly neutral. In tanning, the arsenic is used as calcium sulph-arsenite, and it was desirable to know if the form in which the arsenic is present in the sewage would have any effect upon the results of the operation of filters. From June 18 to July 11, 1908, 25 parts of arsenic as As_2S_3 were mixed with the sewage applied to Filter No. 338, which had hitherto been operated with sewage containing no arsenic. Nitrification continued as before, and no difference could be noted as the result of the application of the arsenic in the form of sulphide.

From the results obtained it is evident that not only may nitrification become established in new filters, to which a sewage containing small amounts of arsenic is applied, but that enormous amounts of arsenic may be applied to filters which are in a state of active nitrification, without ill effect, provided the amount be increased gradually.

The removal of arsenic by the various filters varied considerably. The smallest amount, 76.5 per cent., was removed by Filter No. 335, when it was receiving sewage containing a very small amount of arsenic. Later, when the proportion of germicide applied to this filter was increased, the removal was over 99 per cent. Filters Nos. 337, 338 and 342 removed 99.5 per cent., 99.7 per cent. and 99.8 per cent. of the arsenic, respectively. The removal by Filter No. 345 varied with the amount of arsenic in the applied sewage, although the difference in the percentage removal at different times was extremely small. When 25 to 50 parts arsenic were being applied to this filter the removal was about 99.98 per cent. As the amount of arsenic in the dose was increased the removal slightly decreased, and when 200 to 500 parts arsenic were being applied the removal averaged about 99.62 per cent. Examination of the sand after the filters were stopped showed that Filter No. 335 had stored 28.4 per cent. and Filter No. 342, 26.0 per cent. of the arsenic applied. What had become of the arsenic not accounted for, it was impossible to determine, although it was suspected that part of it had combined with the iron of the tanks in which the filters were contained. To determine in what measure arsenic would be retained by the sand, a small glass filter containing 18 inches of clean sand was flooded for sixty days at a rate of 100,000 gallons per acre daily with distilled water containing 25 parts of arsenic. At the end of this period analyses showed that 9.7 per cent. of the applied arsenic had been stored in the sand.

Effect of Naphthalene.

The tannery sewage previously discussed frequently contained naphthalene, and it seemed possible that this might have caused the failure of filters operated with that sewage to nitrify. After nitrification had

been established in Filter No. 338, sewage was applied for some weeks which had been allowed to stand twenty-four hours in contact with naphthalene crystals. As far as could be determined the presence of naphthalene in the sewage had no effect whatever upon nitrification.

Effect of Sulphides.

After nitrification had become active in Filter No. 344 a solution of sodium sulphide, free from caustic, equivalent to 5 parts H_2S per 100,000, was mixed with the applied sewage, this amount being gradually increased until it reached a maximum of 25 parts. There was no appreciable effect noted in the action of the filter due to the presence of the increased amounts of sulphides, nor could any trace of H_2S ever be detected in the effluent, even with the most delicate tests.

Effect of Bleaching Powder.

In connection with studies on the sterilization of sewage and the effluents from sewage filters by chlorine, bleaching powder was mixed with the sewage applied to a number of the filters during 1908. During August, September and October bleaching powder equivalent to 2.5 parts per 100,000 available chlorine was mixed with the sewage applied to Filter No. 10, one of the large intermittent filters in the field outside the station. During June and July the nitrates in the effluent from this filter averaged over 2.0 parts per 100,000, and during the three months when bleaching powder was applied no diminution in the amount of nitrates was noted.

During the same months, August 1 to November 1, the combined effluents from Filters Nos. 135 and 136 were treated with bleaching powder equivalent to 2.5 parts available chlorine per 100,000 before being applied to secondary Filters Nos. 224, 249 and 250. All of these filters were actively nitrifying when the bleaching powder was first applied and continued to do so during the experiment.

On April 3, 1908, the mixing of bleaching powder with the settled sewage applied to Filter No. 248 was begun. The disinfectant was first applied in the proportion of 0.5 part available chlorine per 100,000, this amount being gradually increased until in August, September and October the available chlorine in the applied sewage was 5.0 parts. During the first four months of the experiment the only noticeable change in the effluent from this filter was an increase in chlorine. In August. when the bleaching powder had been increased to an equivalent of 5.0 parts available chlorine per 100,000, the nitrates in the effluent decreased from about 2.0 parts to about 0.75 part, and there was an increase in the amount of nitrites. During September and October the

nitrites gradually decreased to the normal, but there was no corresponding increase in the nitrates. No changes in the analytical results other than those mentioned were observed. In reporting similar experiments on the application of sewage containing bleaching powder to trickling filters at the Hamburg Experiment Station, Schwartz[1] records an entire cessation of nitrification, and the appearance of considerable amounts of chlorates in the effluent when bleaching powder, equivalent to about 2.5 to 7.0 parts available chlorine per 100,000, was added. In the experiments with Filter No. 248, about 5.0 parts available chlorine were applied without any serious ill effect. No trace of chlorates could be detected in the effluent from this filter at any time, nor were they to be expected if their formation was the result of nonnitrification, as stated by Schwartz.

These experiments show that, if necessary, sewage may be sterilized by chlorine added as bleaching powder without affecting its subsequent purification by intermittent sand or by trickling filters.

Effect of Copper Sulphate.

In addition to the experiments described, large single doses of copper sulphate have been applied occasionally to the surface of a number of filters of coarse materials during the past few years for the purpose of checking fungous growths or destroying growths of the larvæ of insects, by which the upper layers of the filters had become clogged. Such treatment has usually accomplished the desired results with entire success, and, as far as could be determined, has had no detrimental effect upon the purification by the filter. In fact, the reverse has been true, in that conditions more favorable for nitrification have been provided by the destruction of the clogging growths when the treatment was successful.

Conclusions.

The knowledge acquired from the experiments made during the earlier years concerning the conditions governing the process of nitrification has been far reaching in its influence upon the development of practically all methods of sewage purification. The experiments with albumen and peptone showed that nitrification was independent of the form in which the albuminoid nitrogen was present in the sewage. The experiments with ammonia showed that large amounts of readily oxidizable nitrogen may be converted quickly and completely into nitrates in passing through a filter. In the presence of an excess of alkali, nitrification was unimpaired, but a deficiency of alkali caused an incomplete oxidation of the

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[1] Schwartz, Ges. Ing., 1906, 205.

ammonia, or at least a decrease in the nitrates of the effluent. The excessive quantities of nitrates in the sewage applied to Filter No. 15A had little or no effect upon the process of nitrification, the nitrates coming through the filter unchanged, nor was any different result to be expected unless the conditions were favorable for a reducing process. The experiments proving the necessity of oxygen and determining the amount required for nitrification were important, and established the fundamental law of sewage purification, that not only is nitrification an oxidizing process which can take place only in the presence of free oxygen, but that only so much oxygen need be present as is necessary for complete oxidation, provided this oxygen is evenly distributed throughout the material.

The other experiments illustrate the adaptability of the nitrifying body to the conditions imposed, and establish another fundamental law of sewage purification, that, if nitrification is to continue in the presence of an excess of any substance, the filter must become slowly accustomed to the presence of that substance by application of it in gradually increasing amounts; that when once accustomed to considerable amounts of any substance the process of nitrification will proceed unimpaired. This fact was discovered at the very beginning of the experiment with ammonia, and is to be seen in the results obtained with the various filters to which different antiseptic substances, such as common salt, mercuric chloride, phenol, formalin and arsenic and bleaching powder, were applied. In every case the application of large amounts of these substances caused a cessation of nitrification, but when they were applied in gradually increasing amounts nitrification continued unimpaired. The experiments with sugar, with soap and with urine apparently contradict this law, but, when explained, the exceptions prove the rule. Sugar is not a nitrogenous body and could not be converted into nitrates. Hence when it was applied alone nitrification ceased, but when it was applied with sewage there was no decrease in nitrification. The effect of soap may be explained in a like manner. Not only is soap a non-nitrogenous compound, but the fatty acids of which it is composed are broken down but slowly by bacterial action, and these, accumulating in the surface layers of the filter, shut off the air supply and in this way check nitrification. In explaining the results obtained with urine, we must take into account the fact not only that a filter must become accustomed to its dose, but also that there is a limit to the amount of raw nitrogenous matter which may be applied to any filter. When the dose applied to the urine filters greatly exceeded this limit, as was the case at first, no nitrification occurred. When, however, the dose was reduced below this limit, and the filter had become adapted to its work,

an enormous nitrification occurred. Undoubtedly had the urine filters been started with small doses, and gradually worked up, not only would nitrification have become established sooner, but much larger doses could have been successfully purified.

Trickling Filters.

Filters Nos. 15, 16, 15A, 16A, 15B, 16B, 51, 52, 66, 82, 117, 131, 134, 135, 136, 196, 247, 248, 222, 233, 234, 235 and 236.

Trickling, or sprinkling, filters are an outgrowth of studies in regard to the bacterial purification of sewage made at the station during the first three years of its operation. In the early Lawrence work, after the first principles of successful intermittent sand filtration had been well worked out, various filters of coarse materials were constructed, and the changes that occurred in sewage when passed through such filters carefully noted and recorded in the special report for 1890 and in subsequent reports.

Twenty years ago, in June, 1889, a filter of gravel-stones was put into operation at the station, the stones used being of such size that they would pass through a screen "having a mesh three-eighths of an inch square but not through a screen having a mesh one-eighth of an inch square."[1] On the same date, another filter was constructed, of coarse gravel, the stones being of such size that none "were less than three-fourths of an inch in diameter nor more than one and one-fourth inches."[2] Good nitrification occurred in these filters, 99 per cent. of the bacteria in the sewage applied was removed, and in summarizing the results, it was stated "that the purification of sewage by nitrification and the removal of bacteria is not to any essential degree a mechanical but a chemical change." Also that "the experiments with gravel-stones give us the best illustration of the essential character of intermittent filtration of sewage, — the slow movement of the liquid in films over the surface of the stones with air in contact."

One of these filters, No. 16A, was operated between November, 1890, and July, 1891, at a rate as high as 200,000 gallons per acre daily, and the sewage was applied frequently, sixty to seventy doses a day being given.[3] This was the first trickling filter to be operated at the station, and at the present time the sewage of several million people in England and of several hundred thousand in Germany is purified upon filters of this type. Dr. Dunbar, director of the Hamburg State Hygienic Institute, and one of the most experienced and thoroughly informed men in

[1] See page 563, special report of Massachusetts State Board of Health on "Purification of Sewage and Water," 1890.

[2] See page 549, same report.

[3] Page 555, report for 1891.

the world in this line of study, makes the following statements in his book, "Principles of Sewage Treatment," recently issued. The paragraphs quoted relate to both contact and trickling filters.

Of much more general importance, however, are the experiments which have been carried out at the Experiment Station erected at Lawrence. By selecting the most suitable soil, attempts were made to increase the efficiency of the method, and, finally, such coarse material was used that the sewage passed straight through, without spreading over the filter. Automatic devices had to be adopted to distribute the sewage. The London authorities became aware of these experiments and had them repeated. In 1892 Santo Crimp prepared experimental filters of similar coarse material at Barking, but, instead of adopting an automatic device for distributing the sewage, he allowed the sewage to remain in contact with the filter material. The results produced were so satisfactory that a one-acre filter was constructed of coke, and in this London sewage was treated after its previous treatment with lime and copperas. Dibdin, who was then chemist to the London County Council, has fully reported upon the results of these experiments. The method was not called "intermittent filtration," but "biological method," and the name was changed later to "bacterial purification." The filters were not termed intermittent filters, but bacteria beds.

In 1896 Dibdin recommended the adoption of this method at Sutton, a small town near London, for the treatment of crude sewage without any previous chemical precipitation. During the first years the results were very satisfactory, and the Sutton experiments aroused the interest of all concerned with sewage purification. In numerous English towns experimental works were constructed to test the efficacy of the so-called "bacterial" methods. The above details were not strictly adhered to in the mode of operation; in fact, there was almost every possible variation, as we shall see later. It is not generally known that simultaneously, and independent of Dibdin, J. Corbett, the borough surveyor of Salford, worked out a biological method of purification. His method was likewise based on the Massachusetts experiments; but in its further development it has surpassed the London methods.

In 1893 Corbett of Salford developed the artificial biological method in an entirely new direction. This he did independent of the London experiments, basing his experiments on the results obtained in Massachusetts. Corbett attempted to apply the principle laid down by Sir E. Frankland, and recognized to be correct by the Massachusetts authorities, viz., that in intermittent filtration the liquid should always be allowed to flow freely away. In adopting coarse material in order to purify larger volumes of sewage, it had been found difficult to bring the sewage into sufficient contact with the filtering material. It simply passed through the large pores of the filter unpurified. We have already seen how attempts were made to overcome this difficulty in Massachusetts by means of an automatic syphon arrangement, which discharged sewage on to the filter every twenty or thirty minutes. This method

was not directly applicable on a large scale. The chief difficulty to be overcome was to obtain a uniform distribution of the sewage over the entire surface of the filter. After many experiments in various directions Corbett adopted for this purpose fixed spray jets, from which the sewage was distributed under pressure, in the form of a fountain. At this point it should be mentioned that, in Corbett's opinion, he was the first to place a layer of half pipes underneath the filters, in order to increase aeration and facilitate drainage.

It will be noticed that the above paragraph refers entirely to the distribution of sewage and not to the method of filtration.

Other quotations to the same effect could be given from many authorities but the following is certainly worthy of insertion: —

The vogue of the contact bed is a case in point. It was introduced with no kind of scientific justification, and in this respect was quite different from the percolating filter, which obviously embodied the conditions required for the work of the nitrifying organisms in a much more satisfactory way, and had already been the subject of careful investigation in the United States. —. From "The Surveyor and Municipal and County Engineer" (London, Eng.) of Oct. 9, 1908. Article by Scott-Moncrieff.

Aerated Trickling Filters.

In 1892 two gravel-stone filters, Nos. 15B and 16B, were put in operation in such a way that air was drawn down through them. The rate of these filters, which were continued in operation until 1898, was at times as high as 500,000 gallons per acre daily. In 1895 two additional filters were constructed, Nos. 51 and 52, one of gravel-stones of the same grade as that used in the construction of the filters just mentioned, that is, with an effective size of 5.30 millimeters, and one constructed of pieces of coke of the same size as the gravel just mentioned. These two filters, also, were aerated by forced draft, the air being blown up through them. The average rate of filtration of each was 712,700 gallons per acre daily and the rate for several months of their operation was 1,000,000 gallons per acre daily. In each of the four filters mentioned good nitrification occurred, and the amount of aeration was reduced from time to time until it approximated only about two hours out of each twenty-four. These filters produced effluents of the true trickling filter type, high in nitrates but also containing much free ammonia and partially oxidized organic matter. The nonputrescible character of these effluents was noted and discussed in the report of the Board for 1895, page 469.

Filter No. 66, another artificially aerated filter, was constructed in March, 1896, of 60 inches in depth of gravel of an effective size of 5.10 millimeters, but in order to remove suspended matters in the sewage

and to cause good distribution, during a considerable portion of its period of operation this filter had over its surface 6 inches in depth of coke breeze. A circular opening 8 inches in diameter was left free of coke, however, to allow aeration.

Average Yearly Analyses of Effluents of Filters Nos. 15B, 16B, 51, 52 and 66.

Filter No. 15B.

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.
1892,	206,000	.99	0.5278	.1296	8.34	0.5584	.0483	0.74
1893,	405,000	.59	0.6865	.1433	8.47	0.9427	.0204	0.82
1894,	474,000	.75	1.0626	.2793	7.75	1.2450	.0327	1.65
1895,	448,800	.55	0.9712	.1714	12.21	1.8900	.0675	1.22
1896,	354,900	.50	0.6571	.1849	9.66	2.5000	.0117	0.72
1897,	355,000	.50	0.6797	.1135	8.30	1.6700	.0070	0.64

Filter No. 16B.

1892,	206,000	.93	0.4823	.1209	8.23	0.4772	.0524	0.72
1893,	432,000	.55	0.5416	.1561	8.58	1.0338	.0761	0.86
1894,	463,000	.61	1.0000	.1797	7.74	1.3817	.0198	1.07
1895,	465,300	.44	0.7402	.1560	11.87	1.3900	.0431	1.02
1896,	315,600	.90	1.8575	.2106	9.65	1.5000	.0107	1.25
1897,	323,000	.63	1.0917	.2669	7.90	1.9700	.0112	1.28

Filter No. 51.

1895,	712,700	.92	2.0446	.3788	11.32	0.9500	.1389	2.46

Filter No. 52.

1895,	712,700	.84	2.0037	.2592	11.64	0.4900	.0592	1.63

Filter No. 66.

1896,	351,800	.62	1.1972	.3628	10.69	2.2900	.0848	2.49
1897,	657,000	.58	1.3228	.3327	7.35	1.1600	.0118	1.73

Trickling Filters without Artificial Aeration.

On April 12, 1897, Filter No. 82 (see report for 1897, page 451), constructed of 5 feet in depth of cinders containing little fine material, began to be operated as a trickling filter without forced aeration. Across the filter and about 10 inches above its surface an iron pipe with small orifices along its lower half was extended parallel to the filter surface. The sewage was delivered from a tank above the surface level, and, as stated in the report for 1897, "the pressure of the sewage caused it to rush from the pipe with considerable force in a large number of broken streams, and by means of this scattering, and the spraying caused by the sewage striking the surface of the filter, considerable air was introduced into the sewage, etc." During a portion of its period of operation, moreover, an iron dash-plate was placed below the orifices. This filter was operated for five months in this manner at an average rate of about 500,000 gallons per acre daily and good nitrification and a stable effluent resulted.

In May, 1899, a filter, No. 117, was constructed of 10½ feet in depth of broken stone (see report for 1899, page 448). Sewage was applied at a rate of 2,000,000 gallons per acre daily, and this filter, also, was not artificially aerated. It was operated for seven months only, but during that period produced a highly nitrified, stable effluent containing free oxygen. In November, 1899, Filters Nos. 135 and 136 were constructed and are still in operation. These filters, at first constructed of 18 feet in depth of broken stone, but soon reduced to 10 feet in depth, have received sewage at average rates of more than 1,500,000 gallons per acre daily, and at times the rates have for long periods approximated 3,000,000 gallons per acre daily. These filters also, as in the case of all the filters subsequently mentioned in this chapter, have always been operated without artificial aeration. From time to time other filters operated in this manner have been started, seventeen in all to date, and at the end of 1908 seven such filters were being operated at Lawrence. In all this work the adaptability of different filtering materials for use in the construction of such filters, the effect of different depths of filter and of different rates of filtration have been carefully studied. In addition, the quality of the effluents produced, judging by the usual analytical standards and by incubation or putrescibility tests, the character of the sediment in the effluents, as compared with the sediment in sewage, and the degree and rapidity of clogging by the storage of retained matters and methods of distributing sewage to their surfaces, have all been given due attention. The length of the period of operation now attained by several of these filters makes the Lawrence data upon the last point especially valuable.

Eight trickling filters of broken stone have been operated, as follows: —

Filter Nos.	Depth of Filter.	Average Rate (Gallons per Acre Daily).	Length of Period of Operation.
117,	10 feet 5 inches.	2,000,000	- 7 months.
134,	5 feet -	1,180,000	2 years 2 months.
135,[1]	10 feet -	1,511,800	9 years 1 month.
136,[1]	10 feet -	1,797,300	9 years 1 month.
196,	5 feet 4 inches.	1,148,000	- 9 months.
222,[1]	8 feet -	1,394,600	5 years 5 months.
247,	5 feet -	1,465,100	4 years 3 months.
248,[1]	8 feet -	1,490,800	4 years 4 months.

[1] Still in operation.

Length of Period of Operation.

It will be seen from this table that at the present time certain of the Lawrence trickling filters are in their tenth year of operation, namely, Filters Nos. 135 and 136. Filter No. 248, of less depth and still in operation, was started more than four years ago, and Filter No. 222, five and one-half years ago.

Size of Stone used and Depth of Filter.

Filters Nos. 117 and 134 were constructed of stone, practically all of which would pass through a sieve with two meshes to the linear inch and little or none through a sieve with a ¼-inch mesh. Filters Nos. 135 and 136, 247 and 248 were constructed throughout their entire depth of stone, all of which would pass through a screen with one mesh to the linear inch, 40 per cent. through a screen with a ½-inch mesh and about 4 per cent. through a screen with a ¼-inch mesh. The stone in Filter No. 247 contained a slight percentage more of fine material than did Filters Nos. 135, 136 and 248, and this slight difference had some influence in causing clogging in Filter No. 247, as will be discussed later. The stone used in these filters, owing to the long, narrow-shaped pieces into which it breaks, appears to be somewhat coarser than these figures indicate. Filter No. 222 has, over Akron pipe and field stone underdrains, about 7 feet in depth of broken stone of a different character, ranging from 1½ inches to 3 inches in diameter. Filter No. 196, operated for only nine months, was 5 feet 4 inches in depth, as follows: at the bottom, 1 foot of field stone from 6 to 8 inches in diameter; above this a layer 1 foot in depth of similar stone from 4 to 6 inches in diameter; then 1 foot in depth of stone from 2 to 4 inches in diameter; 1 foot 9 inches in depth of stone from ½ to 2 inches in diameter; 3 inches of stone none of which was over ½ inch in diameter, and over the surface 4 inches in depth of a mixture of buckwheat coal and small pieces of coke.

It will be seen from these statements that the size of material used in these stone trickling filters has varied considerably in different filters and that the depth of filters studied has varied from 5 to 18 feet.

Rates of Filtration and Character of Sewage applied.

The rates at which these different filters have been operated have varied from 1,000,000 to 4,000,000 gallons per acre daily. The average rates are shown in a preceding table. These averages show practically the true rates of operation of Filters Nos. 117, 134 and 196 for their entire period of operation. Filters Nos. 135, 136, 247, 248 and 222, however, have been operated at times at much higher rates than the averages indicate. Filter No. 135, for instance, was operated at a rate of 2,400,000 gallons per acre daily during 1903, and for the past two years the average rate of Filter No. 136 has been about 2,350,000 gallons per acre daily. Filters Nos. 117 and 196 received regular station sewage, so called; Filters Nos. 247 and 248, regular station sewage until October, 1906, since when they have received the supernatant sewage from a settling tank. Filter No. 135 received station sewage during 1899, 1900, 1904, 1905 and 1906 until October; during 1901, 1902 and 1903 sewage that had been passed through a coal strainer was applied to this filter, and since October, 1906, supernatant sewage from station sewage after a period of sedimentation. To Filter No. 136, septic sewage was applied during 1900, 1901, 1902 and 1903, but during 1904, 1905 and 1906, until October, regular station sewage; since October, 1906, supernatant sewage from allowing regular sewage a period of sedimentation has been applied. Filter No. 222 has always received Andover sewage that has passed through the settling tank at the Andover filtration area, — a strong, ill-smelling, almost septic sewage. The tables of analyses of applied sewage are presented here.

Sewage applied to Filter No. 135.

[Parts per 100,000.]

Year.	Ammonia.			Kjeldahl Nitrogen.		Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.	Sewage applied.
	Free.	Albuminoid. Total.	Albuminoid. In Solution.	Total.	In Solution.				
1900,	4.09	.62	.27	1.27	.55	9.02	4.31	1,499,400	Regular.
1901,	6.41	.35	.29	0.72	.59	9.70	2.08	383,300	Strained.
1902,	5.31	.36	.25	0.74	.51	8.50	2.12	656,100	Strained.
1903,	4.05	.39	.24	0.80	.49	9.96	2.90	5,077,000	Strained.
1904,	5.15	.95	.47	1.83	.87	12.31	4.86	1,927,300	Regular.
1905,	2.98	.47	.25	0.92	.47	8.94	3.35	1,605,000	Regular.
1906,	4.54	.67	.38	1.18	.63	12.99	4.57	1,632,100	Regular.
1907,	4.92	.58	.33	1.01	.57	14.81	4.70	666,800	Settled.
1908,	4.83	.50	.31	0.92	.55	14.18	3.83	1,108,500	Settled.
Average,	4.70	.54	.31	1.04	.58	11.16	3.64	1,617,300	

Sewage applied to Filter No. 136.

[Parts per 100,000.]

Year.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Kjeldahl Nitrogen. Total.	Kjeldahl Nitrogen. In Solution.	Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.	Sewage applied.
1900,	4.67	.38	.22	0.68	.45	9.74	2.45	648,800	Septic.
1901,	5.98	.39	.29	0.80	.59	8.73	2.58	352,000	Septic.
1902,	4.52	.43	.27	0.88	.55	11.25	2.85	1,020,000	Septic.
1903,	3.80	.35	.22	0.72	.45	9.91	2.93	1,183,900	Septic.
1904,	5.15	.95	.47	1.83	.87	12.31	4.86	1,927,300	Regular.
1905,	2.94	.48	.25	0.82	.47	9.23	3.26	1,605,000	Regular.
1906,	4.46	.64	.37	1.19	.66	13.08	4.60	1,632,100	Regular.
1907,	4.92	.58	.33	1.01	.57	14.81	4.70	666,800	Settled.
1908,	4.88	.50	.31	0.92	.55	14.18	3.83	1,108,500	Settled.
Average,	4.59	.51	.30	0.98	.57	11.47	3.56	1,127,200	

Sewage applied to Filter No. 247.

[Parts per 100,000.]

Year.	Temperature (Deg. F.).	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Kjeldahl Nitrogen. Total.	Kjeldahl Nitrogen. In Solution.	Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1904,	61	5.25	.95	.47	1.91	.88	13.65	4.80	1,903,800
1905,	54	2.86	.48	.26	0.91	.48	8.78	3.45	1,605,000
1906,	54	3.80	.57	.37	0.97	.68	12.17	4.09	1,632,100
1907,	58	4.92	.58	.33	1.01	.57	14.81	4.70	666,800
1908,	57	4.83	.50	.31	0.92	.55	14.18	3.83	1,108,500
Average,	57	4.33	.62	.35	1.14	.62	12.72	4.17	1,383,200

Sewage applied to Filter No. 248.

1904,	61	5.25	.95	.47	1.91	.88	13.65	4.90	1,903,800
1905,	54	3.27	.58	.30	1.13	.51	8.48	3.91	1,605,000
1906,	54	3.76	.56	.37	1.02	.61	11.96	4.22	1,632,100
1907,	58	4.92	.58	.33	1.01	.57	14.81	4.70	666,800
1908,	57	4.83	.50	.31	0.92	.55	14.18	3.83	1,108,500
Average,	57	4.41	.63	.36	1.20	.62	12.61	4.29	1,383,200

Sewage applied to Filter No. 222.

[Parts per 100,000.]

Year.	Temperature (Deg. F.).	Ammonia.			Kjeldahl Nitrogen.		Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid. Total.	Albuminoid. In Solution.	Total.	In Solution.			
1903,	57	5.52	.74	.46	1.53	.95	7.69	4.27	2,459,000
1904,	52	3.41	.70	.38	1.56	.81	4.69	2.73	2,091,000
1905,	43	2.98	.55	.38	1.08	.76	5.16	2.71	1,317,000
1906,	-	2.84	.41	.29	0.70	.49	5.34	2.43	608,300
1907,	56	2.78	.47	.33	0.99	.66	6.54	3.68	1,755,000
1908,	62	3.67	.64	.43	1.27	.85	7.99	4.75	2,301,200
Average,	54	3.52	.59	.38	1.19	.75	6.23	3.43	1,755,300

Quality of Effluents obtained. — Nitrification. — Incubation Tests. — Stability.

All these filters have produced effluents containing nitrates, and with equal rates of filtration the nitrates have increased as the depth of the filter. The nitrates in Filters Nos. 135 and 136 have averaged over 2 parts per 100,000 for their entire period of operation, and were greater during the years 1906 and 1907 than in previous years, or 4.36 and 3.65 parts per 100,000, respectively, in 1906, and 4.46 and 3.00 parts per 100,000, respectively, during 1907. This degree of nitrification has been obtained with Filter No. 135 operating at a rate of 1,500,000 gallons and with Filter No. 136 at a rate of more than 2,000,000 gallons per acre daily. The nitrates in the effluent of Filter No. 248, 8 feet in depth, have averaged 1.77 parts per 100,000, and in the effluent of Filter No. 247, 5 feet in depth, 0.62 part per 100,000, these filters having been operated over four years, up to the end of 1908, at average rates of 1,491,000 and 1,465,000 gallons per acre daily, respectively. Filter No. 196, constructed of 5 feet 4 inches in depth of the graded material described previously, and operated at a rate of 1,143,000 gallons per acre daily, produced an effluent containing 0.61 part per 100,000 of nitrates, and Filter No. 222, also constructed of coarse stone, of less size than that in Filter No. 196, however, and operating with Andover sewage at a rate of 1,400,000 gallons per acre daily, has produced an effluent containing an average of 0.45 part per 100,000.

Throughout this work, incubation tests have been made to show the stability or nonstability of the effluents. The effluent of each filter has contained a large percentage of the organic matter in suspension present in the applied sewage, but freed from most of its easily putrescible bodies. For example, the effluents of Filters Nos. 135 and 136 have contained 37 and 48 per cent., respectively, of the organic matter in the applied sewage determined as albuminoid ammonia; the effluent of Filter No. 247, 55 per cent.; the effluent of Filter No. 248, 82 per cent.; and the effluent of Filter No. 222, 64 per cent. As stated previously, these effluents have not in any sense resembled the effluents of sand filters in freedom from organic matter, but are modified sewages; that is, water still containing much organic matter but of a stable instead of an unstable or putrescent nature such as characterizes organic matter in sewage. In other words, owing to the oxidizing conditions existing in such filters, the residual organic matter in their effluents is made stable when the rate of operation of the filter is properly adjusted to its depth, to the quality of the filtering material and to the strength of the sewage applied. Filter No. 196, 5 feet 4 inches in depth, constructed of the graded coarse material previously described, and operated at a rate of more than 1,000,000 gallons per acre daily, produced an effluent that putrefied at least 75 per cent. of the time. The effluents of Filters Nos. 117 and 134 were almost invariably nonputrescible. All of the samples of effluent collected from Filters Nos. 135 and 136 have been nonputrescible, 90 per cent. of those from Filter No. 248, 8 feet deep, and about 45 per cent. of those from Filter No. 247, constructed of the same grade of material as the filters just mentioned, but 3 feet less in depth than Filter No. 248 and half as deep as Filters Nos. 135 and 136, these shallower filters having been operated at lower rates, however, than Filters Nos. 135 and 136. It has been noticeable that a stable effluent has been produced even when nitrates were not present.

The following table presents a summary of the quality of the effluents in respect to stability, together with figures showing the depth and the size of material of each filter: —

Summary of Incubation Tests on Effluents from Trickling Filters from June, 1902, to December, 1908.[1]

Filter Nos.	Depth.	Material Finer than —	Material.	Per Cent. of Samples of Effluent not Stable.
135,	10 feet,	1 inch,	Broken stone,	0
136,	10 feet,	1 inch,	Broken stone,	0
196,	5 feet 4 inches,	Graded,	Broken stone,	70
222,	Varied,	–	Broken stone,	14; putrefaction slight.
247,	5 feet,	1 inch,	Broken stone,	56
248,	8 feet,	1 inch,	Broken stone,	8; putrefaction slight.
233,	5 feet 9 inches,	1¾ inches,	Clinker,	10; putrefaction slight.
234,	8 feet 10 inches,	1¾ inches,	Clinker,	42
235,	5 feet 9 inches,	¾ inch,	Clinker,	0
236,	8 feet 10 inches,	¾ inch,	Clinker,	47

[1] During this time there were four periods, a total of about twenty months, when no tests were made.

During 1906, samples of the effluents from all trickling filters in operation during that year were incubated as usual, — duplicate samples of each effluent after the removal of much of the matters in suspension by three hours' sedimentation, and samples of the entire effluent — that is, effluent containing sediment — mixed with equal volumes of tap water, that is, the drinking water of the city of Lawrence. None of the samples so tested putrefied with five days' incubation, with the exception of 22 per cent. of those from Filter No. 247, a filter 5 feet in depth; this effluent was so poor that these samples putrefied even after the suspended matters had been removed, and nearly half of them when mixed with equal volumes of tap water.

Many investigations and experiments have been made in relation to the keeping qualities of trickling filter effluents, and in relation to the changes occurring when such effluents are mixed with sewage or water, as well as comparisons of their behavior under various conditions. One such characteristic experiment was as follows: duplicate samples of the effluents of Filters Nos. 135, 247 and of a good tap water were each mixed with 5, 10, 25 and 50 per cent. by volume of sewage, respectively, and incubated. At the end of a week all mixtures of the effluent of Filter No. 247 had become darker in color, and those containing 25 and 50 per cent. of sewage were black, on account of the formation of sulphides; the mixture of the highly nitrified effluent of Filter No. 135

with sewage remained unchanged in appearance, but that containing 50 per cent. by volume of sewage had developed a fairly strong, sour odor. All the mixtures of tap water and sewage had at the end of this period a strong and decided sewage odor, and that containing 50 per cent. by volume of sewage had begun to blacken.

Character of Sediment in Effluents.

Many examinations of the sediment in the effluents have been made and described in the various reports of the past eight years, and the two following tables illustrate the difference between this sediment and that of untreated sewage: —

Analyses of Sediments from Sewage and Effluents of Filters Nos. 135 and 136.

	Sewage Sediment.	Sediment of Filter. No. 135.	Sediment of Filter. No. 136.
Per cent. of total nitrogen (Kjeldahl),	2.37	1.37	1.41
Per cent. of nitrogen determined as albuminoid ammonia,	1.30	0.70	0.78
Per cent. that albuminoid ammonia is of total nitrogen (Kjeldahl),	55.00	51.00	55.30
Albuminoid ammonia (parts per 100,000),	1,575.00	851.00	952.00
Loss on ignition (parts per 100,000),	58.50	27.60	31.50

Experiments with Water and Sediments (River Water saturated with Oxygen): .2 Gram of Sediment and 4,000 cubic centimeters of Water in Each Case.

	Dissolved Oxygen at End of Five Days (Per Cent. of Saturation).
River water at end of five days,	90.0
Filter No. 135, sediment and river water,	100.0
Filter No. 136, sediment and river water,	76.0
Sewage sediment and river water,	1.5

Average analyses of the effluents of Filters Nos. 117, 135, 136, 196, 222, 247 and 248 are here given: —

Average Analysis of Effluent of Filter No. 117.[1]

[Parts per 100,000.]

Quantity Applied. Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.) Sewage.	Temperature (Deg. F.) Effluent.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1,897,000	63	63	.42	.7265	.0963	5.96	1.88	.1247	1.09	144,000

[1] Operated for seven months during 1899.

Average Yearly Analyses of the Effluents of Filters Nos. 135 and 136.

Filter No. 135 (Ten Feet deep).

[Parts per 100,000.]

Year.	Quantity Applied. Gallons per Acre Daily.[1]	Appearance. Turbidity.	Appearance. Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Kjeldahl Nitrogen.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1900,[2] . .	899,900	-	1.12	3.4353	.1606	.1049	.2897	7.64	0.23	.0045	1.42	183,000
1900,[3] . .	1,804,900	-	0.64	2.5212	.2080	.1448	.3752	10.54	0.45	.0131	1.33	431,500
1901, . . .	1,406,900	-	0.81	3.1645	.2228	.1358	.4019	9.44	2.40	.0132	1.57	87,300
1902, . . .	1,817,400	-	0.52	1.7452	.1392	.0856	.2510	8.61	2.76	.0071	1.08	45,800
1903, . . .	2,398,600	-	0.67	1.6000	.1473	.0983	.2658	9.02	1.47	.0107	1.37	51,100
1904, . . .	1,150,400	8.0	0.57	0.7047	.2889	.1143	.5212	11.17	2.95	.0064	2.30	77,300
1905, . . .	1,304,000	4.5	0.86	0.7178	.2158	.1059	.3563	8.08	3.47	.0054	1.69	50,700
1906, . . .	1,469,100	4.7	0.50	0.4437	.2335	.1422	.4128	12.60	4.36	.0061	2.03	28,400
1907, . . .	1,708,100	3.7	0.60	0.9329	.3522	.1663	.6480	14.23	4.46	.0061	2.78	29,400
1908, . . .	1,463,600	1.5	0.60	1.0067	.2827	.1658	.4443	13.83	2.96	.0097	2.12	26,500
Average, .	1,542,300	4.5	0.69	1.6272	.2251	.1258	.3966	10.52	2.55	.0082	1.77	101,100

Filter No. 136 (Ten Feet deep).

Year.	Quantity Applied. Gallons per Acre Daily.[1]	Appearance. Turbidity.	Appearance. Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Kjeldahl Nitrogen.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1900,[2] . .	747,600	-	0.58	3.4278	.1646	.1066	.2969	7.58	0.16	.0170	1.20	120,300
1900,[3] . .	1,004,700	-	0.58	2.2230	.1245	.1131	.2246	10.41	2.20	.0179	1.09	57,800
1901, . . .	1,402,700	-	0.82	3.4153	.2331	.1344	.4204	8.62	2.00	.0086	1.67	73,000
1902, . . .	1,809,100	-	0.60	2.3553	.1930	.1050	.3483	9.06	2.66	.0091	1.36	54,400
1903, . . .	2,257,300	-	0.66	1.6565	.2161	.1027	.3898	9.88	1.91	.0089	1.84	64,600
1904, . . .	1,938,000	10.5	0.68	1.3883	.3348	.1509	.6080	11.06	2.05	.0096	2.39	123,900
1905, . . .	2,082,000	6.4	1.14	1.2855	.2911	.1256	.5161	8.29	2.19	.0102	2.26	81,300
1906, . . .	2,099,200	7.5	0.58	0.8316	.3481	.1952	.6452	12.73	3.65	.0094	2.83	41,300
1907, . . .	2,454,200	5.8	0.69	2.1192	.4993	.3136	.8572	14.28	3.00	.0083	3.72	55,400
1908, . . .	2,292,200	2.7	0.63	1.1779	.3114	.2278	.5351	13.88	2.26	.0079	2.43	42,500
Average, .	1,808,700	6.6	0.70	1.9880	.2716	.1575	.4837	10.58	2.21	.0107	2.08	71,500

[1] During 1899 (two months), 1900, 1901, 1902, and after April 8, 1906, these filters were operated seven days a week; during 1903, 1904, 1905 and the first three months of 1906, six days a week.

[2] November 28 to April 15.

[3] April 16 to December 31.

Average Yearly Analyses of the Effluents of Filters Nos. 196, 247, 248 and 222.

Filter No. 196 (Five Feet Four Inches deep).

[Parts per 100,000.]

Year.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Appearance.		Ammonia.	Albuminoid.		Kjeldahl Nitrogen.	Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Turbidity.	Color.	Free.	Total.	In Solution.			Nitrates.	Nitrites.		
1903, . . .	1,142,600	00.0	0.69	2.4760	.2926	.1170	0.0000	9.52	0.61	.0202	2.06	245,300
Filter No. 247 (Five Feet deep).												
1904, . . .	925,500	8.6	0.68	2.8100	.3075	.1931	-	12.01	0.52	.0216	1.60	390,300
1905, . . .	1,368,200	8.5	1.68	2.2632	.3737	.1935	0.7684	8.84	0.49	.0091	2.52	427,[illegible]00
1906, . . .	1,218,000	13.7	0.85	2.4493	.4642	.2811	0.8743	12.22	0.82	.0300	3.44	185,500
1907, . . .	1,901,500	7.4	0.87	3.7917	.6475	.3497	1.1826	14.61	0.84	.0156	4.51	148,200
1908, . . .	1,912,500	4.2	0.83	2.9852	.5678	.3176	1.0549	14.15	0.44	.0119	3.62	361,300
Average, .	1,465,100	8.5	0.98	2.8599	.4720	.2670	0.9700	12.37	0.62	.0176	3.18	302,600
Filter No. 248 (Eight Feet deep).												
1904, . . .	963,400	10.0	0.73	4.0924	.5775	.2813	-	11.23	2.12	.0572	2.81	409,000
1905, . . .	1,365,800	8.7	1.39	1.9180	.3666	.1816	0.8537	7.78	1.14	.0108	2.71	236,800
1906, . . .	1,297,000	10.9	0.82	1.6672	.7471	.2463	1.4402	11.96	1.88	.0363	4.69	91,000
1907, . . .	1,889,300	6.1	0.76	2.2417	.5963	.2738	1.0260	14.48	2.06	.0155	3.74	54,700
1908, . . .	1,938,400	3.0	0.66	1.7792	.4783	.2438	0.8052	15.88	1.64	.0277	3.17	296,500
Average, .	1,490,800	7.7	0.88	2.3397	.5532	.2454	1.0313	12.27	1.77	.0295	3.42	217,600
Filter No. 222 (Eight Feet deep).												
1903, . . .	1,404,800	-	0.89	3.5571	.4562	.2385	-	6.60	0.64	.0642	2.18	861,300
1904, . . .	1,465,000	3.4	0.57	2.5706	.4733	.2141	-	5.20	0.65	.0246	2.23	891,000
1905, . . .	1,471,000	3.3	0.58	2.5951	.4312	.2576	0.8367	6.05	0.59	.0318	2.05	594,300
1906, . . .	1,750,000	1.3	0.52	2.3332	.1820	.1490	0.2978	6.26	0.25	.0097	1.26	119,500
1907, . . .	982,200	1.0	0.47	2.8622	.1908	.1601	0.3299	5.90	0.02	.0011	1.36	651,000
1908, . . .	1,344,300	-	0.63	2.3850	.4298	.2342	0.8312	7.93	0.53	.0565	2.69	798,000
Average, .	1,394,600	2.3	0.60	2.7172	.3606	.2089	0.5739	6.32	0.45	.0312	1.95	650,800

Trickling Filters of Clinker, etc. — Depth. — Quality of Effluents.

Trickling filters of clinker and one of broken brick have also been operated at the station. In fact, the first trickling filter of the modern type was a cinder or clinker filter, No. 82, 5 feet in depth, started

April 12, 1897, as previously stated in this chapter. Besides this filter, four others of clinker have been operated at a later period, namely, Filters Nos. 233, 234, 235 and 236. Filters Nos. 233 and 234 were constructed of pieces of clinker varying in diameter from ¾ to 1¾ inches, while Filters Nos. 235 and 236 were constructed of pieces varying from ¼ to ¾ inch in diameter. Filters Nos. 233 and 235 were 5 feet 9 inches in depth, while Filters Nos. 234 and 236 were 3 feet 10 inches. These four filters were put into operation Jan. 1, 1904. Filters Nos. 234 and 236 were continued for thirteen months only, while Filters Nos. 233 and 235 were in operation until the end of 1908, a period of five years. Regular station sewage was applied to Filters Nos. 234 and 236 during their entire period of operation and to Filters Nos. 233 and 235 until October, 1906. After that date clarified or supernatant sewage was applied. The average rate of operation of these filters was about 1,000,000 gallons per acre daily, and all of them produced well-nitrified effluents, the best nitrification occurring, as was to be expected, in the filters of the finer material. The stability of the effluents of these cinder filters is discussed in connection with that of the effluents of the stone filters. The broken brick filter, known as Filter No. 189, was constructed of 10 feet in depth of pieces of broken brick about 2 inches in diameter, and was started in May, 1902, and continued until May, 1904, a period of two years. Regular station sewage was applied to it at an average rate of 2,100,000 gallons per acre daily. Good nitrification occurred within it, the average nitrates in its effluent averaging over 1 part per 100,000, but its effluent was putrescible fully 80 per cent. of the time. The average analyses of the effluents of these filters during their period of operation follow.

Average Analyses of the Effluents of Filters Nos. 82, 189, 233, 234, 235 and 236 during their Period of Operation.

Filter No. 82 (Cinder).

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Kjeldahl Nitrogen.	Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid. Total.	Albuminoid. In Solution.			Nitrates.	Nitrites.		
518,500	.57	1.3300	.1819	.1393	-	9.21	1.03	.0221	1.14	393,300

Filter No. 189 (Broken Brick).

2,098,700	.90	2.5438	.4163	.1631	-	9.44	1.16	.0329	2.54	451,900

Average Analyses of the Effluents, etc. — Concluded.

Filter No. 233 (Clinker). In Operation 5 Years.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Kjeldahl Nitrogen.	Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid.				Nitrates.	Nitrites.		
			Total.	In Solution.						
1,018,600	.77	2.3023	.4150	.2814	.8232	11.51	1.27	.0219	2.81	305,100
Filter No. 234 (Clinker).										
949,000	.88	3.4225	.4707	.2431	.8492	10.16	0.73	.0768	2.80	717,000
Filter No. 235 (Clinker). In Operation 5 Years.										
1,022,900	.68	1.3258	.3354	.1574	.6167	12.07	2.20	.0261	2.49	296,800
Filter No. 236 (Clinker).										
908,900	.77	3.5721	.4411	.2254	.8708	11.18	0.50	.0127	2.48	637,300

Trickling Filters in Winter.

During the winters of 1906–07 and 1907–08, broken stone Filter No. 222, previously described, received sewage by the overhead distributor and dash-plate method to be described later in this chapter. The winter of 1906–07 was very cold in New England, while that of 1907–08 was considerably milder. The temperature records for the three coldest months of each winter are given in a following table, these records being those of the experiment station, about 2 miles from the Andover filtration area, at which Filter No. 222 is located. During the first winter from 55 to 60 inches of snow fell, and of this total depth about 50 inches fell between January 12 and February 24, snow falling on seventeen days during this period. During nearly all this period the distributing apparatus worked almost as well and as successfully as during warm summer weather. At times, however, one or more of the nozzle outlets became clogged with floating matter in the sewage and froze; but this clogging occurs in warm weather at all areas where sewage nozzle distribution is practiced, and at such times the outlets have to be cleaned, it being necessary at large areas abroad to keep men busy at this work. Occasionally with Filter No. 222 clogging occurs in the supply pipe. During the coldest weather of these winters all the outlets worked

satisfactorily and freezing did not occur unless the orifices first became somewhat clogged. While snow at times accumulated on portions of the filter, and the area on which sewage was distributed became lessened, still a considerable circle around each outlet was kept free by the sewage applied, and the filter remained in good operation. A table showing the temperature records during these two winters and a table from the caretaker's note-book of operation for the winter of 1906–07 are given here.

Maximum and Minimum Temperatures, in Degrees Fahrenheit, at the Lawrence Experiment Station (Day ending at 8 A.M.).

Day of Month.	December, 1906.		January, 1907.		February, 1907.		December, 1907.		January, 1908.		February, 1908.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
1,	45	7	47	32	32	19	33	18	41	27	-	-
2,	26	9	41	21	42	23	32	11	40	19	45	6
3,	32	0	51	21	24	9	32	14	34	23	-	-
4,	17	8	53	29	20	5	31	20	36	12	16	-5
5,	33	15	42	24	13	3	32	15	37	10	18	-7
6,	46	26	42	26	20	-7	35	12	-	-	35	12
7,	31	-5	53	28	24	-3	42	23	35	14	34	14
8,	13	11	37	31	27	-3	54	17	51	33	20	2
9,	17	10	40	4	27	3	-	-	40	24	31	-3
10,	34	17	34	5	35	20	61	40	36	13	-	-
11,	26	4	42	20	29	-3	57	38	36	14	37	15
12,	23	6	38	16	13	-4	39	25	-	-	-	-
13,	34	21	35	19	36	0	36	19	48	25	36	13
14,	31	21	34	20	49	25	34	22	44	25	47	32
15,	45	29	38	2	33	19	37	24	31	10	-	-
16,	38	25	18	-10	39	24	-	-	39	25	57	19
17,	35	17	14	-5	38	12	37	26	39	11	-	-
18,	23	0	30	13	28	8	35	24	34	23	31	13
19,	25	2	46	45	33	11	34	12	-	-	23	13
20,	35	13	53	20	39	21	33	16	36	6	34	21
21,	37	27	23	8	36	4	40	25	54	24	36	10
22,	38	23	29	0	15	-13	42	15	53	38	-	-
23,	24	11	10	-11	-	-	47	28	42	24	40	33
24,	22	12	7	-10	25	-4	48	35	26	13	28	9
25,	21	17	14	5	33	0	43	25	32	11	37	0
26,	30	12	22	-6	20	5	-	-	58	20	38	26
27,	42	23	22	0	22	-3	51	19	-	-	39	30
28,	39	23	26	-1	25	3	50	37	30	14	39	23
29,	44	30	26	2	-	-	50	25	24	35	33	13
30,	-	-	31	-5	-	-	-	-	19	-3	-	-
31,	36	34	22	1	-	-	44	29	40	7	-	-

DECEMBER, JANUARY AND FEBRUARY RECORDS FROM CARETAKER'S NOTE-BOOK.

Average Temperature of Applied Sewage and Effluent. — Filter No. 222.

	Applied Sewage (Degrees F.).	Effluent (Degrees F.).
December, 1906,	46	44
January, 1907,	42	41
February, 1907,	40	38

December 29, Settling tank emptied. Filter stopped three hours. The remainder of day filter ran as usual but registering device had become clogged with sludge.

January 7, 4 P.M., to January 9, 4 P.M., sewage running at same rate as usual but supply pipe was partially clogged and siphon did not work properly.

January 18, Settling tank emptied. Filter stopped five and one-quarter hours.

February 1, Settling tank emptied. Filter stopped two and one-half hours.

February 3, 3 outlets stopped.

February 4, 1 outlet stopped.

February 5, 1 outlet stopped.

February 6, 1 outlet stopped.

February 7, 1 outlet stopped.

February 9, 1 outlet stopped.

February 12, 1 outlet stopped.

February 13, 3 outlets stopped.

February 22, Settling tank emptied. Filter closed two and one-half hours.

Surface Clogging and its Removal.

During the operation of these filters surface clogging has occurred as follows: twice in Filter No. 136 on account of an enormous growth of small worms[1] in the upper few inches of the filtering material; once in Filter No. 135 for the same reason, and once in Filter No. 222 by the growth of an amorphous jelly-like mass of bacteria. Filters Nos. 135 and 136 were put out of operation for a few days and the worms died. They undoubtedly could have been eliminated more quickly by the use of a germicide, such as copper sulphate, and this salt was applied to Filter No. 222 at the time of clogging, in the sewage passed to the filter. The growth of bacteria was killed quickly and disappeared, the filter continuing in good operation.

Storage of Matter in Filters.

None of the stone filters, with the exception of Nos. 222 and 247, have given trouble from stored matters, organic or mineral. Filters Nos. 135 and 136, after nine years' operation, have stored practically only 2.5 per cent. of the organic matter in the sewage applied, and are as open and pass sewage as freely now as when put into operation. Filter

[1] One feature of the operation of trickling filters is the prevalence of large numbers of small moth flies (*Psychoda alternata*) during the summer. The larvæ of these flies breed in the upper layers of the filter, and are so numerous at times as to completely clog the filter and prevent the entrance of sewage, as has been noted in discussion of Filters Nos. 135 and 136 and the Andover filter. The flies themselves are feeble in flight and do not travel far unless carried by the wind, but on and about the filters they are so thick at times as to be a veritable nuisance to the filter attendants.

No. 247 has clogged so badly that the filtering material has had to be removed and cleaned, this being due partly, as before stated, to the somewhat finer stone in this filter and partly to clogging by fatty matters, owing to experiments upon the disposal of such matters added to the applied sewage. Filter No. 222, owing to the grading of the filtering material, has given trouble at times on account of clogging. Filter No. 233 stored during its period of operation about .5 pound of matter per cubic foot of filtering material, while Filter No. 235, of finer material, stored practically three times as much, or 1.4 pounds per cubic foot of filtering material. Examination of the filtering materials for the determination of stored matter has given the following results: —

Pounds of Matter stored per Cubic Foot of Filtering Material, and Analyses thereof, Filters Nos. 135, 136, 233, 235, 247 and 248.

Filter Nos.	Pounds per Cubic Foot.	Per Cent. by Weight.						
		Ammonia.		Kjeldahl Nitrogen.	Carbon.	Hydrogen.	Loss on Ignition.	Fats.
		Free.	Albuminoid.					
135, . . .	.57	.35	1.26	2.63	28.47	3.79	41.0	1.40
136, . . .	.19	.51	3.44	6.26	31.24	3.91	62.6	4.40
233, . . .	.77	.30	1.81	3.35	-	-	45.9	2.82
235, . . .	.54	.48	1.53	3.55	-	-	45.6	2.31
247, . . .	.30	.17	2.48	5.50	22.49	3.71	61.2	7.35
248, . . .	.42	.19	1.70	4.81	-	-	57.2	3.46

The following diagram (No. 16) shows the per cent. of nitrogen applied to Filters Nos. 135, 136, 233, 235, 247 and 248; that lost, that appearing as organic nitrogen, nitrates and free ammonia in the effluent of each filter, and that stored within the filter up to the end of 1908.

Time taken by Sewage to pass through Trickling Filters of Coarse Material operated at High Rates.

It has always been the custom at Lawrence to study the length of time taken for the passage of sewage through the different materials used in the filters. Attention has been drawn already to the fact that as early as 1889 the rate of flow through the sand filters was determined by examinations of applied sewage and of the effluent for chlorine. In 1904 determinations were made of the rate of flow through trickling filters. At this time this work was carried on just as in the early years; that is to say, sewage containing a known amount of salt was applied to the filter and careful determinations made of the chlorine in the effluent before, during and after the application of this salt.

With Filter No. 135, containing 10 feet in depth of broken stone and operated at the time of the experiment at a rate of 1,500,000 gallons per acre daily, it was about one hour after the application of salt sewage

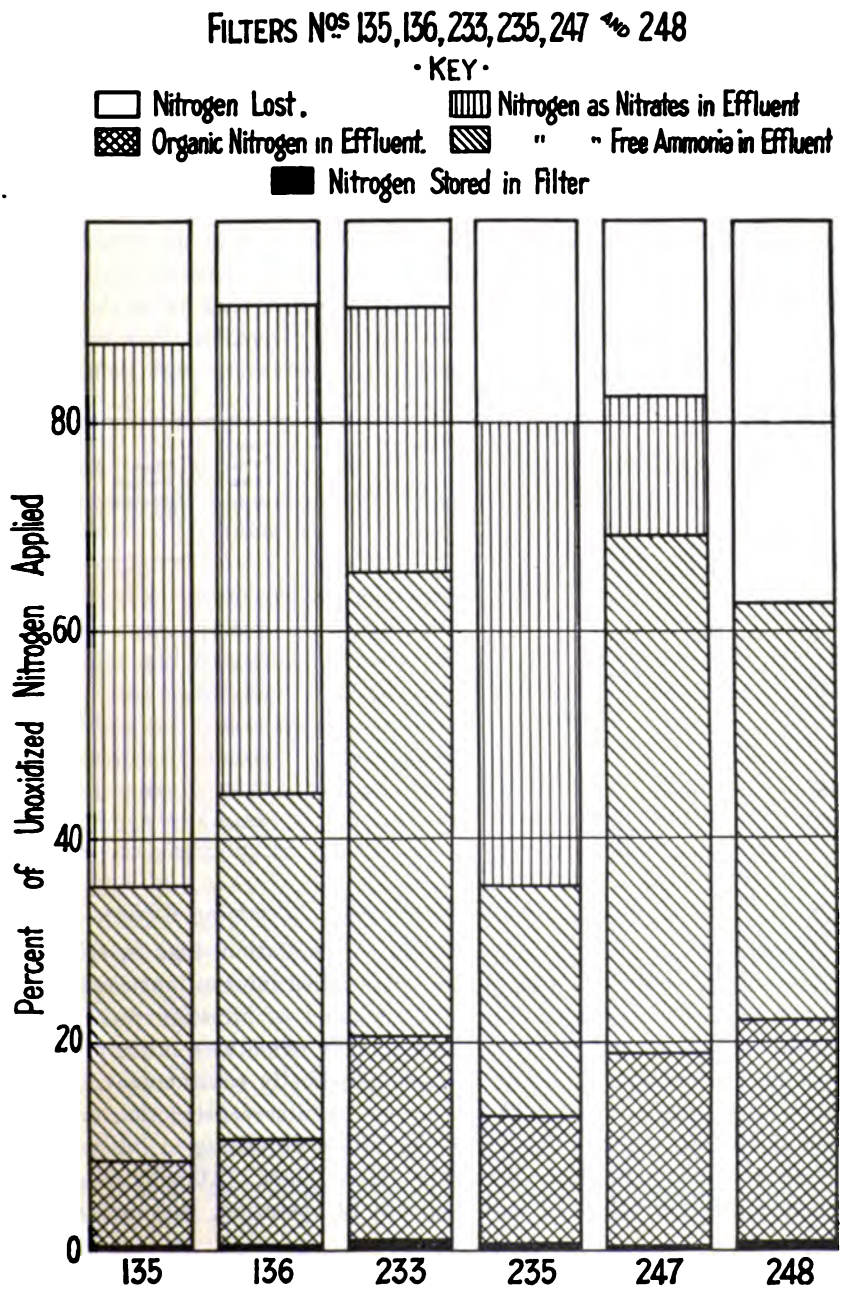
before any of it appeared in the effluent. From this time the chlorine increased rapidly, until at the end of three hours the effluent contained 92 per cent. as much chlorine as in the applied sewage, this being the highest percentage found.

With Filter No. 136, constructed of the same kind and size of filtering material but operated at a rate 70 per cent. greater than Filter No. 135, the maximum amount of chlorine was found in the effluent about two hours after the application of salt sewage.

Further experiments of the same kind were made with Filters Nos. 247 and 248, constructed of broken stone, and with Filters Nos. 233, 234, 235 and 236, constructed of clinker.

Filter No. 247 contains 5 feet in depth of broken stone, and at the time the experiment was made the rate of operation was 1,000,000 gallons per acre daily. An increase in the amount of chlorine in the effluent of this filter was noted at the end of fifteen minutes, and it increased steadily for about two hours. The amount then became constant, the highest amount found in the effluent being 90 per cent. of the amount applied. With Filter No. 248, containing 8 feet in depth of broken stone, the amount of chlorine present in the effluent increased appreciably at the end of half an hour, and after about two hours became constant, the maximum amount found in the effluent being about 81 per cent. of the amount in the sewage applied. Filters Nos. 233, 234, 235 and 236 are constructed of clinker, Nos. 233 and 235 being constructed of coarse clinker and Nos. 234 and 236 of a finer grade of clinker. The rate of operation of each of these filters was, at the time of experiment, 1,000,000 gallons per acre daily. With Filter No. 233, containing 5 feet 9 inches in depth of coarse clinker, the chlorine in the effluent increased appreciably in from fifteen to twenty minutes, and from that time on steadily, until, at the end of six hours, it became fairly constant. Filter No. 234, of the same grade of material and only 3 feet 10 inches in depth, showed an increase of chlorine in its effluent in fifteen minutes or less; and the amount became constant one hour after the application of the salt sewage was begun. In Filter No. 233 the highest chlorine found in the effluent was 80 per cent.; in Filter No. 234, 86 per cent. of that in the applied sewage. The deeper filter of fine clinker did not show an increase of chlorine in the effluent until about one and one-half hours from the beginning of application of salt sewage, and the amount found slowly increased for fourteen hours before it became constant. With the shallower filter of fine clinker, the increase in chlorine could be noted at the end of one and one-half hours; it gradually increased for six hours before becoming constant. The maximum chlorine in the effluent of Filter No. 235 was 72 per cent. of the chlorine in the salt

Diagram No. 16.



sewage; and in the effluent of Filter No. 236, 79 per cent. It was noticeable that in none of the experiments did the chlorine in the effluent become equal to the chlorine in the applied salt sewage, although this salt sewage was applied for many hours; this being due to the fact that a certain volume of the sewage previously applied was held even in these filters of coarse material, and this, being slowly given up and mingling with the salt sewage applied, reduced its chlorine content. It was also plain, because of the greater length of time taken for the chlorine in the effluent of the clinker filters to reach a constant amount, that these filters held a much greater percentage of sewage in their pores than the filters of broken stone. This was due to the porosity and unevenness of the material, and had, of course, a beneficial influence upon the purification effected by the filters. The following table shows the effect upon nitrification of the depth of the filters, of their materials and the time required for the passage of the sewage through them: —

Filter Nos.	Depth.		Material.	Average Rate, 1904 (Gallons per Acre Daily).	Time of Passage of Sewage (Hours).	Nitrates (Parts per 100,000).
	Feet.	Inches.				
185,	10	0	Broken stone,	1,150,000	3	2.95
186,	10	0	Broken stone,	1,988,000	2	2.05
247,	5	0	Broken stone,	925,500	2	0.52
248,	8	0	Broken stone,	963,400	2	2.12
233,	5	9	Coarse clinker,	885,000	6	1.24
234,	8	10	Coarse clinker,	949,000	1	0.73
235,	5	9	Fine clinker,	896,500	14	2.20
236,	8	10	Fine clinker,	908,900	6	0.50

Conclusions in regard to Sprinkling or Trickling Filters.

When these filters were first operated at the station, that is, trickling filters without artificial aeration, they were called intermittent-continuous filters, and, if named according to the manner of filtration rather than to the method of application of sewage, that name was entirely proper inasmuch as sewage is passing to them practically continuously. It is, however, so intermingled with air, owing to filter construction and the rate of application, that the aerobic conditions prevailing in intermittent filters are always maintained within these filters. Abroad, moreover, where municipal filters of this type are in operation, they are almost

invariably operated intermittently; that is, sewage is applied for an hour or two, then a period of rest allowed.[1] As stated in the first Lawrence report, "slow movement of the liquid in films over the surface of the stones with air in contact is the essential characteristic of intermittent filtration of sewage." The main difference between sprinkling filters and intermittent sand filters is that, owing to the size of the open spaces between the particles of filtering material in the sprinkling filters, much greater rates can be maintained and still allow the free entrance of air. Sprinkling filters are not a substitute for sand filters, which remove practically all the matter in suspension in sewage, but are simply devices for the modification of sewage, or, in other words, the quick oxidation of the putrefying matters present while allowing the larger body of stable matters and matters rendered stable by filtration to pass through. From the results obtained at the station, it is evident that with filters 10 feet deep, constructed of sufficiently fine material and operated with such sewage as has been used at Lawrence, rates of at least 2,500,000 gallons per acre daily can be maintained with good nitrification and with an almost invariably nonputrescible effluent. The effluent will, however, contain much residual organic matter. When the rate is increased to 3,000,000, 3,500,000 or 4,000,000 gallons per acre daily the effluents deteriorate in appearance and quality, although even at the higher rates an effluent can be obtained which is often stable and which when mixed with water containing free oxygen, will improve. If the rates are lowered to 1,000,000 gallons per acre daily, a rate beyond which such filters are hardly ever operated abroad,[1] a much better looking effluent is obtained than when the rate is twice as great. The effluents of filters operated at this comparatively low rate are of such quality that the matters in suspension quickly settle, leaving a clear, supernatant liquid, — a liquid resembling in appearance the effluents of sand filters. With depths of filter less than those just discussed, the rates of operation must be materially decreased if equally good results are desired, as shown by Filter No. 247, 5 feet in depth. In order to obtain nonputrescible effluents, fairly good nitrification in these filters is generally necessary, judging from the Lawrence results, and if the filtering material is broken stone it certainly should not be coarser than that of Filter No. 222. Stone as fine as that in Filters Nos. 135 and 136 will produce the best results. The grade of filtering material used may be varied according to the character of the applied sewage; that is, a finer material may be used

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[1] See paper on "Some Observations of Methods, Costs and Results of Sewage Purification Abroad," by H. W. Clark (Journal of the Association of Engineering Societies, Vol. XLI., No. 5, November, 1908).

with a supernatant sewage from sedimentation or chemical precipitation than when the sewage contains much suspended matter. It follows, of course, that the finer the filtering material and the clearer the sewage, the better the effluent, but too fine a material cannot be used, as surface pooling ensues and air is excluded.

Methods of Distributing Sewage on Filters.

The question as to the proper method of distributing sewage upon filters, and the effect of unequal distribution upon the quality of the filter effluents, has received attention from the very beginning, and it was determined early that the best results were obtained when the sewage was distributed most uniformly over the surface; and with filters no larger than the experimental filters, this is of course easily accomplished. In 1888 a mechanical distributor was tried upon Filter No. 1 for some months, this being described in the special report for 1890 as follows: —

> A distributor was devised, consisting of four flat arms forming a cross, suspended horizontally at the middle, with edges projecting from half an inch to a sixteenth of an inch above to upper surface. Sewage is applied at the middle, and flows out on the four arms, overflowing the edges and running out at the ends, a foot from the sides of the tank. By revolving the cross 90 degrees and back while the sewage is running on, it becomes evenly distributed over the surface. This was put up and first operated Nov. 22, 1888, since which time the impurities of the effluent have been so much less than for the previous three months that it becomes more than probable that during those months the results were much affected by the uneven distribution of sewage over the surface. — Special report for 1890, p. 25.

With intermittent sand filters the sewage will find its way over a considerable area, even when large volumes are applied at points quite a distance apart, the fineness of the material and the clogging of the surface preventing the dose passing through the filter too rapidly at the point of application. An absolutely uniform distribution of the sewage over the surface of such filters is therefore unnecessary, and simple forms of distributing channels or sewage carriers serve the purpose. In the report for 1892 the essential requirements of a sewage distributor for intermittent filters were stated to be as follows: —

> There is one point in regard to the construction of sewage carriers which has often been mentioned but which will still bear discussion. All carriers for sewage should be so made that when a bed has been flooded and the

sewage turned in another direction every particle of sewage should drain out of the carrier. The area of the bed immediately about the outlets of the carriers might with advantage be slightly higher than the rest of the surface. With clean sand there would be an advantage in distribution by allowing a slight slope from the outlets in all directions to the most distant parts of the filter; but if the total difference in level of the different portions of the filter exceeded a few inches, there would be too great a tendency to form ponds in the low places when the surface became clogged. — Report for 1892, p. 418.

The experience of many years, however, has shown that with sand areas varying in many particulars, and in operation both summer and winter, the methods of distribution and the form of the carriers may be essentially different from this description. The use of channels covered with snow and ice, and lower than the general filter surface, constitutes an especially good method of winter distribution.

The method of applying sewage to contact filters at the station has been similar to that for intermittent filters, but less pains have been taken to distribute it evenly over the surface. Perforated pipes have been placed above the surface of some of these filters, and upon others revolving arm distributors, operated on the principle of Barker's mill, have been used. The systems of perforated pipes and jets used upon Filter No. 82 and upon the Andover coke filter will be described later. The object of most of these devices upon contact filters has been to provide aeration of the applied sewage, or to prevent displacement of filter material, rather than to obtain uniform distribution, although the latter object was more or less completely attained by their use. The nature of the operation of contact filters is such that the sewage will find its way to all portions of the bed in any event, and beyond the prevention of undue accumulation of suspended matter on portions of the surface, or the disturbance of the material, the question of distribution is of minor importance, and systems used for intermittent filters may be applied also to this type.

With trickling filters, however, the efficiency depends largely upon the spraying or scattering of the sewage uniformly over the whole surface, and the failure of otherwise well-designed filters of this type to produce an effluent of good quality may often be attributed to improper distribution of the sewage. The distribution experiments on Filter No. 1, in 1888, previously described, show that this fact was fully appreciated long before the trickling filter as now known was developed. The apparatus devised and tried at that time was probably the earliest attempt to obtain uniform distribution by mechanical means, and was

the forerunner of the various types of mechanical distributors so commonly used on trickling filters in recent years. In fact, a power-driven device almost identical in principle is now in use on certain English trickling filters.

Since these early experiments, many different types of distributors have been used and the results of their operation studied. It was discovered early that, if efficient distribution of the sewage was to be obtained, and if the filter was to be operated continuously at a reasonably low rate, it would be necessary for the sewage to flow into some form of apparatus which would store it up and apply it automatically at frequent intervals, in doses of such size that each part of the filter surface might receive its portion. This gave rise to the very descriptive name of intermittent-continuous filters, which was applied to the Lawrence trickling filters for some years. In 1891 an intermittent-continuous device, consisting of a tank fitted with an automatic siphon discharging sewage upon a dash-plate on the surface of the filter, was tried upon Filters Nos. 15A and 16A. The reasons for its trial and the results were stated as follows: —

> The filter appeared to do most of its work during the hours when sewage was applied, and it seemed quite probable that it was capable of doing as much additional work during the night as it was then doing in the day. To settle this point an automatic feed was arranged, which delivered sewage equivalent to 2,800 gallons per acre at intervals of from twenty to thirty minutes during days, nights and Sundays. The reservoir of sewage was replenished every morning and no other attention was required. Owing to imperfections in the apparatus employed the delivery was not absolutely regular, but afterwards improvements were made in the regulator which insured good work. The results, although not so good as had been obtained during the previous year, with half the quantity applied, were still very satisfactory. — Report for 1891, p. 555.

This method of distribution was used also upon some of the other early trickling filters at the station. With most of the early filters of this type, however, the distribution was generally accomplished by pouring the sewage upon a dash-plate. A similar method was employed with the larger filters, such as Nos. 51 and 52, operated in 1895. In this case, however, the sewage was pumped to an elevated tank from which the required volume was run out upon a distributing plate at stated intervals by the filter attendant.

In 1897 a somewhat different method of distribution was used upon Filter No. 82, this being described as follows: —

The sewage applied to this filter goes to the surface in the following manner: across the filter and about 10 inches above its surface an iron pipe is placed, with small orifices extending along its lower half. This pipe is parallel to the filter's surface. The sewage is pumped to a tank elevated above this level, to which the delivery pipe is attached, and when the gate is opened the pressure of the sewage causes it to rush from the pipe with considerable force in a large number of broken streams, and by means of this scattering, and the spraying caused by the sewage striking the surface of the filter, considerable air is introduced into the sewage. — Report for 1897, p. 451.

Flat pieces of sheet iron were placed upon the surface of this filter to prevent erosion, and further served to break up and distribute the flow over the surface.

In 1896 the surface of a trickling filter, No. 66, was covered with a fine coke to aid distribution and a circular opening left in the fine material to allow aeration. (See page 502, report for 1896.)

In 1898 a different method of obtaining intermittent action and uniform distribution was devised for use upon small trickling filters. This has proved so satisfactory that it has been employed constantly upon such filters since that time. This device consists of a wedge-shaped tipping basin divided into two equal compartments, supported by trunnions upon a perforated distributing pan. The sewage flows continuously at the required rate into one compartment, which, when full, overbalances the weight of the other side and tips, discharging its contents into the distributing pan and bringing the opposite side under the entering stream of sewage. This device is entirely automatic if kept clean, and has the advantage over the siphon previously used in that its operation is independent of the rate of the entering sewage. The use of this apparatus was first mentioned on page 452 of the report for 1899.

With the installation of a large experimental trickling filter of the Board at Andover, opportunity was afforded to study the effect of different systems of distribution upon a somewhat larger and more practicable scale than had been possible with the small filters at the experiment station. A summary of the various methods of distribution tried was given on pages 191 and 192 of the report for 1907.

During two months in 1899 sewage was applied to this filter through a grid of perforated pipes, from which numerous small jets were shot up into the air and more or less completely distributed by wind action, and various attempts were made to improve the distribution by fastening strips of metal above the orifices to deflect and diffuse the flow. During five months of 1900 the distribution was by means of perforated pipes

elevated above the surface, with the orifices pointing downward, a flat piece of slate being placed beneath each orifice to spread the flow. This application of the overhead carrier system, combined with dash-plates to distribute the flow, upon a sprinkling filter was not new, however, but was an adaptation of the type of distribution which had been used three years before at the experiment station, in connection with Filter No. 82, as previously described. During the latter part of 1900 a considerable amount of sand was dug into the surface of the Andover filter, with the idea of improving the distribution and increasing the efficiency of the filter by forming a layer of fine material upon the top. This method was similar in effect to that by which distribution of sewage by fine layers placed upon the surface of trickling filters is brought about and which has been used in some places in Germany in recent years, and was essentially the same as that used on Filter No. 66 in 1896, as previously described. During the winter of 1903–04 the sewage was applied to the filter at Andover through a perforated grid buried one foot below the surface of the material. From 1904 to 1906 sewage was applied by a large automatic tipping basin, which intermittently flushed one side and then the other of the bed, the distribution of sewage being assisted by sloping the surface away from the tipping basin. In June, 1906, a system of distribution by means of an automatic siphon, connecting by overhead pipes with nozzles and dash-plates, was installed. This was described on page 268 of the report for 1906 as follows: —

At one side of the filter is placed an automatic flush tank, into which a small stream of sewage is kept flowing continuously, and when full the tank empties itself through a siphon into a grid containing seven orifices ½ inch in diameter. The top of this tank is 41 inches and the bottom 8 inches above the outlets. One inch below each outlet, and located 12 inches above the surface of the filtering material, were placed dash-plates, each 2 inches in diameter, with the outer edge turned up at an angle of 45 degrees, making a slight rim about ¼-inch wide. As the sewage flows from the flush tank through the grid and outlets, it strikes upon the dash-plates and is thrown out in a thin sheet, like an umbrella, and breaks into a spray at the outer edge, covering a circle about 5 feet in diameter. As the tank empties, the head operating on the outlets is gradually reduced, and the circle covered by the sewage becomes more and more contracted, until finally, when the tank has emptied, the whole circle has received sewage. The automatic flush tank is of such size that, with the filter operating at a rate of 2,000,000 gallons per acre daily, it will flush about once in nine minutes, about two minutes being required for the tank to empty itself through the seven ½-inch outlets. By this method the sewage is distributed over the filter much more uniformly than by the earlier methods, about

90 per cent. of the surface being sprinkled each time the flush tank operates, while in addition the sewage is very thoroughly aerated before it reaches the stones.[1]

This history of distribution at Lawrence shows steady progress toward more perfect and more practical distribution systems. From the hand discharge upon baffle plates upon the surface of the earlier filters to the automatic siphon, from the overhead perforated pipes and dash-plate method used on Filter No. 82 in 1897 to the overhead systems used on the Andover filter in later years, from the flat pieces of iron on the small filters and the pieces of slate on the Andover filter to spread the discharge of sewage to the cup-shaped dash-plates finally used for the same purpose, the evolution has been natural and inevitable.

Tests of the Efficiency of Sprinkler Nozzles and Dash-plates.

During 1906 and 1907 a series of measurements was made of the distribution effected by a number of sprinkler nozzles and dash-plates, to determine the uniformity of distribution by each, and in what manner the most uniform distribution could be obtained. In all, fifty-two different sprinklers were tested under a variety of conditions of head and elevation above the filter surface. In addition, many tests were made to determine what effect different materials commonly used for trickling filters would have in making the surface distribution more or less uniform. These percolation tests, so called, were continued during 1908, and confirmed strongly the results previously obtained. These experiments were described on pages 190 to 203 of the report for 1907, the conclusions being as follows: —

From the results obtained in the percolation tests it must be concluded that the material in the filters cannot be expected to perform the work of distribution which should rightly be accomplished by the sprinklers, and that attention must be devoted to improving their construction if a more uniform distribution is to be obtained. Experience with experimental trickling filters has shown that good purification may be obtained when they are operated at certain rates, but that when operated at excessively high rates the results are extremely poor. From the experiments with the sprinklers it is seen that, while the mean rate upon the area wet may be kept down to the point where good purification is assured, small portions of this area are receiving the bulk of the sewage at rates many times greater than practical, while the larger portion of the filter is being operated at

[1] On April 22, 1909, a travelling distributor, similar to what is known as the Fiddian type, was installed at Andover, by which a very much more uniform distribution is obtained than was possible with any of the nozzle or dash-plate systems. This will be described in a later report.

a very low rate. The result is that a considerable proportion of the sewage may pass through the filter practically unchanged and a small portion be highly purified; in other words, the effluent from the filter may be a mixture of highly purified effluent and of practically unpurified sewage, rather than a uniformly purified effluent. . . . The sprinkler tests have shown that as the head is increased the size of the area covered by any sprinkler and the rate of discharge by the sprinkler increase, but that the mean rate on the area wet diminishes. The tests have shown also that nearly all sprinklers are more efficient in producing uniform distribution when operated at the higher heads, and that only a small variation in this efficiency is produced by elevating the sprinkler above the surface. The rates obtained with nearly all of the sprinklers have been so large that they could not be operated continuously without causing the filter to be flooded at much higher rates than are at present believed to be advisable; and for this reason a system of distribution by sprinklers of any of these types should also include some device for producing intermittent operation. Operating the sprinklers under variable head has resulted in wetting the portion of the surface adjacent to the sprinkler which was entirely overthrown by the same sprinkler under constant head, but this more complete wetting has not resulted in any material increase in the uniformity of distribution, since a greater volume of sewage is concentrated upon a smaller overdosed area.[1] The shape of the area wet by a sprinkler such as the Salford old style nozzle, in which the spraying is produced by the interference of two jets, is not such as to lend itself readily to the economical placing of the sprinklers on large areas; and the use of external arms to support the deflecting cone in nozzles such as the Columbus type results in a very unequal distribution of the sewage upon different radii in addition to the inequalities normal to ring sprinklers of this class. Nozzles such as the Salford new style, which produce a whirling spray, seem to produce a more uniform distribution than most sprinklers of the deflecting cone or dash-plate type; but the design is such that trouble must be experienced with clogging unless a sewage remarkably free from suspended matter be used. With the types of sprinklers in which the flow is broken up and deflected by cones or dash-plates, the angle at which the spray is projected has considerable influence upon the uniformity of distribution, especially when the sprinkler is operated at higher heads, the best results being generally obtained when the spray is projected at an angle of 15 to 20 degrees above the horizontal. With the cone sprinklers more uniform distribution is produced when the cone is placed close to the orifice than when it is placed some distance away, as is shown by the superior work of the Birmingham nozzle, and of the relative work of the Columbus nozzles with the cones placed in different positions. From the studies with dash-plates and from the relative performance of the Columbus and Birmingham

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[1] The use of a mechanically operated valve to vary the pressure of sewage flowing to nozzles or dash-plates in such a manner that a practically uniform distribution might be obtained, was recommended as a result of these tests. — Gage, "Distribution of Sewage on Trickling Filters," Eng. News, Aug. 20, 1908.

nozzles it has been learned that the distribution is better with small orifices than with large ones, and that it is advisable to keep the size of our orifice of discharge as small as is consistent with freedom from clogging.

It is evident from all the studies of distributing apparatus that the more perfect the distribution the smaller the area of trickling filter necessary to care for a given volume of sewage. The perfect distribution given by certain types of apparatus used abroad, such as the Fiddian or Hanley distributors, enable trickling filter beds to produce effluents of a far more satisfactory quality, other things being equal, than any form of nozzle distribution.

Contact Filters and their Operation.

The comparatively large area required for the purification of sewage by the process of intermittent sand filtration caused English authorities to show more interest in the early Lawrence experiments upon rapid filtration of sewage than in the experiments upon sand filtration. This was so because in England sandy soil suitable for filtration is the exception rather than the rule and sewage farming has failed in many instances. A method of filtration was desired therefore that would purify or care for a larger volume of sewage per acre than was possible with sand filters.

The contact filter and the contact method of operation are generally stated to have had their origin in attempts to pass sewage through a bed of coke breeze continuously during experiments on the treatment of London sewage, made by Santo Crimp and Dibdin, at Barking, from 1893 to 1895. The filters operated at this place were at first run continuously, then from eight to twelve hours a day, and eventually the fill and empty procedure, now so well known as contact filtration, was adopted. To obviate the clogging which resulted from continuous operation, coarse materials were used, and the lack of oxidation when continuous filtration was followed led to the introduction of periods of rest and the contact method. The first filters were constructed of coke, but other materials, such as burnt ballast, cinders, clinkers, broken stone and brick, are used largely in filters of this type.

A contact filter may be described briefly as a bed of coarse filtering material so constructed that the outlets of the underdrains may be closed. The filter is then filled throughout its entire depth with sewage, and this is kept in contact with the filtering material for a definite period. The outlets are then opened, the filter drained, and, after a period of rest or aeration, again filled. The methods of operation followed at different places vary quite materially. In practice, one, two,

three, four or more fillings may be made in twenty-four hours, depending upon the construction of the filter bed, the material used and the quality or strength of the sewage treated.

Continuous filtration through coarse sand was studied at Lawrence in 1888, and the results of these experiments were discussed at some length on page 127 of the special report for 1890. In 1894, before the results of the experiments at Barking had been made public, a filter of gravel-stones was operated by the fill and empty process, or as a contact filter. (See report for 1894, pp. 237 and 267.) The effluent from this filter was turbid, high in free ammonia, but containing a considerable amount of nitrates; in fact, a typical contact filter effluent. After five months' operation as a contact filter, it was changed to an aerated trickling filter, and operated in the manner usually followed with the early trickling filters at the station. The history of contact filters at the station thus dates back to the spring of 1894, but it was not until 1896, or after the work at Barking had been made public by the report to the London County Council, that systematic investigations of contact filters as such were begun. Since that time 32 contact filters, some flooded with untreated sewage, others with clarified sewage, have been operated at Lawrence, and the results have been included in the annual reports.

During these investigations eleven different materials have been employed, 12 of the filters being constructed of coke, 6 of either cinders or clinker, 6 of broken stone, 2 of iron ore, 2 of metallic iron, 1 each of a mixture of metallic iron and coke and a mixture of iron and broken stone, 2 of roofing slate and 1 each of gravel, glass beads and broken brick. Of these filters, 18 have been operated with untreated sewage, 15 with sewage previously strained or passed through settling or septic tanks, and 6 have been operated as secondary filters, with the effluents of other contact filters. A number of these filters have been operated for a short time only for the study of special points of interest, such as the influence of various methods of management or the value of special filter materials, while the operation of others has extended over a number of years, and the results have afforded valuable data regarding the action, the results and the permanency of this type of filter.

On the whole, it may be said that the study of the contact process at Lawrence has been directed mainly toward the determination of the amount of sewage which can be treated per acre by contact filters of different materials or of different grades of the same materials, so as to give a fairly well-purified, nonputrescible effluent. The following table shows the material used in each contact filter, the depth of each, the quantity of sewage applied and the length of the period of operation: —

Schedule of Contact Filters.

Filter Nos.	Material.		Area (Fraction of an Acre).	Sewage applied.	Period of Operation.
	Kind.	Depth (Feet).			
21A, . . .	Gravel, . .	5	1/20000	Regular, ...	March 19, 1894, to Aug. 1, 1894.
81, . . .	Cinders, . .	4½	-	Strained, ...	Nov. 27, 1896, to Sept. 10, 1898.
82, . . .	Cinders, . .	5	1/5000	Regular, ...	April 12, 1897, to Dec. 31, 1900.
103, . . .	Coke, . .	5	1/20000	Septic A, ...	Feb. 28, 1898, to June 30, 1904.
104, . . .	Coke, . .	5	-	Regular, ...	March 19, 1898, to Dec. 31, 1898.
105, . . .	Glass beads, .	5	-	Regular, ...	March 19, 1898, to Dec. 31, 1898.
107, . . .	Cinders, . .	2	1/20000	Regular, ...	April 30, 1898, to Sept. 30, 1899.
108, . . .	Coke breeze, .	2	1/17000	Effluent 107, Strainer C, .	April 30, 1898, to May 31, 1900.
108A, . .	Coke, . .	4	1/20000	Effluent Strainer C, regular,	June 1, 1900, to Dec. 31, 1900.
121, . . .	Iron and coke,	5	1/20000	Effluent Septic A, . .	March 29, 1899, to Sept. 30, 1899.
123, . . .	Iron filings, .	4	-	Regular, ...	May 4, 1899, to Nov. 18, 1899.
125, . . .	Hematite, .	4½	1/60000	Regular, ...	Aug. 1, 1899, to Dec. 31, 1900.
137, . . .	Broken stone,	5½	1/20000	Regular, ...	Feb. 21, 1900, to Dec. 31, 1902.
139, . . .	Stone and iron,	5	1/30000	Regular, ...	Feb. 21, 1900, to May 6, 1900.
154, . . .	Coke, . .	4½	-	Effluent Septic B, . .	Sept. 11, 1900, to Dec. 31, 1900.
163, . . .	Coke, . .	4½	1/20000	Effluent 137, . . .	Jan. 10, 1901, to June 30, 1903.
164, . . .	Coke, . .	4½	-	Effluent 137, . . .	Jan. 10, 1901, to June 30, 1901.
165, . . .	Hematite, .	5	1/20000	Regular, ...	Feb. 3, 1901, to June 30, 1902.
167, . . .	Broken stone,	4	-	Effluent Septic B, . .	March 1, 1901, to Dec. 31, 1901.
173, . . .	Brick, . .	2½	1/25000	Regular, ...	June 4, 1901, to Dec. 31, 1901.
174, . . .	Slate, . .	2½	1/25000	Regular, ...	June 4, 1901, to Dec. 31, 1901.
175, . . .	Coke, . .	5	1/20000	Effluent Strainer E and F,	June 3, 1901, to Nov. 30, 1903.[1]
176, . . .	Coke, . .	5	1/20000	Regular, settled, . . .	June 3, 1901, to Nov. 30, 1903.[1]
180, . . .	Broken stone,	2	-	Effluent 167, . . .	Oct. 1, 1901, to Dec. 17, 1901.
181, . . .	Marble chips, .	4	1/60000	Regular, ...	Oct. 7, 1901, to Dec. 31, 1902.
186, . . .	Slate, . .	4	1/25000	Regular, ...	Jan. 18, 1902, to June 30, 1902.
221, . . .	Broken stone,	3½	1/5000	Regular, settled, . . .	July 7, 1903, to Oct. 27, 1903.
237, . . .	Clinker, . .	5½	1/20000	Effluent 221, . . .	Jan. 1, 1904, to Oct. 28, 1908.
251, . . .	Coke, . .	2½	1/10000	Effluent septic A, . .	Aug. 1, 1904, to Oct. 17, 1908.
Andover large coke.	Coke, . .	5	1/200	Andover regular, Andover septic.	July 1, 1899, to June 30, 1902.
Andover small coke.	Coke, . .	4	-	Andover septic, effluent large coke.	Sept. 12, 1900, to June 30, 1902.

[1] Still in operation.

Contact Filters of Stone (operated at Rates varying from 350,000 to 1,000,000 Gallons per Acre daily).—Filters Nos. 21A, 137, 181 and 221.

Four of the contact filters were constructed of natural stone. Of these, Filter No. 21A was constructed of gravel-stones, Filter No. 137 of broken trap rock, Filter No. 181 of marble chips and Filter No. 221 of broken field stone, largely granite.

The first filter operated at the station by what is now known as the contact process was No. 21A, started March 19, 1894. It contained 5 feet in depth of fine gravel-stones having an effective size of 1.60 millimeters. Regular station sewage was applied each day for six days in the week in twelve doses of equal size at intervals of one-half hour, the outlet of the filter being closed each day before the first application of sewage, and opened part way after the last dose was applied. Operated in this manner, nitrification became established early in May, and in July the nitrates averaged 0.81 part per 100,000. Owing to the fineness of the material of which the filter was constructed, much difficulty was experienced on account of surface clogging, and during June and July the surface was scraped seventeen times and raked on those days when it was not scraped. Beginning July 7 a current of air was drawn through the filter for ten to twelve hours each night, and after August 1 the outlet was allowed to remain open, and the filter was operated as a trickling filter.

Filter No. 137, constructed of 5 feet in depth of broken trap rock of such size that all would pass through a sieve with a 1-inch mesh and none through a sieve with a ½-inch mesh, was put into operation Feb. 21, 1900. Regular station sewage was applied in three doses one hour apart, and it was allowed to stand full two hours before draining, the filter being filled but once daily. Nitrification failed to become established, and the filter was operated as an intermittent filter, at a rate of 100,000 gallons per acre daily for six weeks. Nitrification then appeared and contact operation was resumed, the filter being filled in four doses one hour apart, and the outlet being partially opened immediately after the last dose was applied. Following this, nitrification continued active. From Jan. 9, 1901, to Oct. 1, 1901, the filter was filled twice daily, the sewage being applied in two doses one hour apart. After two hours' contact the outlet was opened and the filter slowly drained, after which the operation was repeated. From Oct. 1 to Dec. 15, 1901, the sewage was applied in four doses at intervals of one-half hour, the other operations remaining unchanged. From Dec. 16, 1901, to Feb. 27, 1902, the filter was filled and drained, as above, three times daily. The effect of filling the filter twice daily was to check nitrification, and during the period

when the filter was filled three times daily the effluent was of even poorer quality than when filled twice a day. In two years this filter, operated six days each week, became badly clogged, and in March, 1902, the material was removed, washed and replaced over new and more open underdrains. This practically new filter was filled once daily, in seven doses applied at intervals of one-half hour with a period of two hours between the last dose and the time the outlet was opened. Nitrification failed to become established under this treatment, and on June 2, 1902, the filter began to be operated as a trickling filter, the outlet remaining open all the time, the sewage being applied as before, in seven doses at intervals of one-half hour. With this change in operation nitrification started, and the effluent was stable and of fair quality up to the time the filter was discontinued, at the end of the year. In the tables below are shown analyses of the effluent during the first two years only, when operated as a contact filter.

On Oct. 7, 1901, Filter No. 181, containing 4 feet in depth of marble chips of the same size as the stone in Filter No. 137, was started. Regular station sewage was applied in three doses one hour apart, the filter standing full two hours before draining and being filled but once daily. Nitrification became established in December, 1901, but the effluent was never of particularly good quality, and the nitrates in the effluent remained low until after July 1, 1902, when the outlet was allowed to remain open all the time and the filter was operated as a trickling filter at the same rate. It was discontinued at the end of December, 1902, and during its period of operation gave the same result as other stone contact filters at the station.

On July 7, 1903, Filter No. 221, containing 3½ feet in depth of broken field stone of such grade that all the pieces would pass a 1-inch screen, 25 per cent. would pass a ½-inch screen and none would pass through a ¼-inch screen, was put into operation. The underdrains of this filter were of open construction, to prevent the clogging of the lower part of the filter, which clogging had been noted in some of the filters previously operated. Regular station sewage was applied in three doses one hour apart, the filter standing full two hours before draining and being filled but once daily. Nitrification became established in the latter part of July, but the effluent, while fairly stable, was never as good in quality as those obtained from the filters of rough and porous materials, to be described later. From Dec. 1, 1904, until it was discontinued, at the end of October, 1908, this filter was filled twice daily, four hours being allowed for draining before the second filling, the filling and contact periods remaining the same as previously described. The effect of filling the filter twice daily was to reduce gradually the already poor nitrification, until during the first six months of 1906

the nitrates averaged only 0.09 part per 100,000. Beginning Aug. 15, 1906, settled sewage was applied. For a few months an improvement in the character of the effluent was noted, and during October, 1906, the nitrates averaged 0.22 part per 100,000. This improvement, however, was only temporary, and during the first six months of 1907 nitrification was very feeble and the effluent was putrescible practically all the time. During this period of about four years the filter had been operated six days a week without rest, and had become badly clogged with organic matter. After July 8, 1907, the filter was rested systematically every sixth week, with the result that the open space increased, nitrification improved and the effluent became of much better quality. During the summer of 1908, however, nitrification again decreased, and as it was evident that the filter was too badly clogged to be satisfactorily operated, it was discontinued in the latter part of October.

The effluents obtained from these four filters are shown in the following tables, together with the rates of operation, these rates varying from 350,000 to more than 1,000,000 gallons per acre daily, or from seven to twenty times as high as the rates of average sand filters: —

Effluent of Filter No. 21A, March 19, 1894, to Aug. 1, 1894.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid.		Nitrates.	Nitrites.			
			Total.	In Solution.					
476,000	.51	2.19	.09	-	0.27	.0178	.62	7.68	86,700

Effluent of Filter No. 137, Feb. 21, 1900, to Jan. 9, 1901.

533,000	.60	2.12	.23	.16	1.10	.0191	1.65	9.55	552,100

Effluent of Filter No. 137, Jan. 10, 1901, to Dec. 15, 1901.

1,027,000	.79	2.94	.29	.18	0.14	.0016	2.04	10.14	383,800

Effluent of Filter No. 137, Dec. 16, 1901, to Feb. 27, 1902.

854,100	.63	2.59	.26	.17	0.05	.0013	1.62	8.93	200,600

Effluent of Filter No. 181, Oct. 7, 1901, to June 30, 1902.

541,700	.72	2.81	.30	.20	0.13	.0011	2.06	8.53	594,700

Effluent of Filter No. 221.

[Parts per 100,000.]

Date.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Kjeldahl Nitrogen.	Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
			Free.	Albuminoid.				Nitrates.	Nitrites.		
				Total.	In Solution.						
1903,[1] . .	566,700	0.81	2.4605	.2916	.1908	-	11.28	.25	.0073	2.48	1,130,700
1904, . .	504,500	0.86	2.1297	.3057	.2195	-	10.20	.14	.0019	2.39	856,000
1905, . .	604,600	1.01	1.5430	.2584	.1996	.5228	8.55	.17	.0081	2.00	509,500
1906, . .	469,200	1.09	2.6352	.2997	.2121	.5490	13.14	.09	.0102	2.35	364,400
1907, . .	350,500	0.94	3.2469	.3580	.2562	.6440	14.33	.14	.0069	2.75	414,200
1908, . .	402,300	0.87	1.9966	.3634	.2541	.6517	13.77	.11	.0137	2.64	484,600
Average,	483,000	0.93	2.3353	.3128	.2221	.5919	11.88	.15	.0080	2.44	626,600

[1] Filter started July 7, 1903; stopped Oct. 27, 1908.

Solids in Effluent of Filter No. 221.

[Parts per 100,000.]

Date.	Unfiltered.			Filtered.		
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1904,[1]	46.3	16.9	29.4	41.3	14.3	27.0
1905, ...	39.8	13.7	26.1	36.1	12.1	24.0
1906, ...	49.8	14.7	35.1	46.6	12.5	34.1
1907, ...	57.5	13.0	44.5	54.0	10.2	43.8
1908, ...	55.4	12.3	43.1	50.2	8.9	41.3
Average, . . .	49.8	14.1	35.7	45.6	11.6	34.0

[1] October, November, and December, 1904.

Contact Filters constructed of Cinders (operated at Rates varying from 240,000 to 730,000 Gallons per Acre daily).—Filters Nos. 81, 82 and 107.

The first filters constructed at the station for the purpose of studying contact action as it is now understood were composed of cinders, and the results obtained with these filters are of interest as first indicating methods to be followed if contact filters were to be operated successfully. Filter No. 81, containing 4½ feet in depth of cinders from which the finer particles had been removed, was started Nov. 28, 1896. Sewage which

had been strained through coke breeze was applied in doses at half-hour intervals until the filter was full, after which it was allowed to stand for two hours before draining. Nitrification started in the latter part of January, 1897, and good results were obtained during the first year of operation. Early in 1898 it was evident that the filter was becoming clogged; nitrification became less active, and in April, 1898, practically ceased, and a reducing action took place in the filter. That is to say, this filter, after being operated without rest for a period of sixteen months, reached such a condition of clogging that a period of rest, or some other method for removing clogging, became necessary. The filter was allowed to rest for two weeks in May, and air was drawn through it constantly. After operation was resumed good nitrification occurred temporarily, but in a few days the reducing action was again apparent, showing that the period of rest had not been sufficient. During June it was still kept in operation, but the effluent was always colored with iron taken into solution from the iron oxides in the filtering material, and nitrification practically ceased. During July a period of rest was again tried, and following this better results were obtained for a short time, but as they did not continue the filter remained out of operation during a large part of the month of August, and in September the results were still so poor that the filter was discontinued. This experiment made it evident that, with the material in the filter and the per cent. of open space, the rate maintained was too great. The filter, furthermore, was so badly clogged that it could not be restored to a satisfactory condition except by removing and washing the material.

On April 12, 1897, Filter No. 82, containing 5 feet in depth of screened cinders was put into operation. It was operated until Sept. 13, 1897, as a sprinkling filter, regular station sewage being applied under pressure through a perforated grid; but on September 14 it began to be operated as a contact filter, regular station sewage being applied through the grid in eight doses at intervals of one hour, until the surface was covered, after which it stood full two hours before draining. Nitrification had become active while it was operated as a sprinkling filter, but the change in the method of operating caused a reduction in bacterial activity, and while the effluent continued to be well nitrified it was not of as good a quality. Owing to clogging, the number of doses applied was reduced to seven on November 2. On Nov. 25, 1897, the period of contact was increased to three hours, and on March 1, 1899, this period was further increased to five hours daily. The effect of increasing the period of contact from three to five hours was noticed in an immediate reduction in the amount of nitrites in the effluent, although no material change

was noted in the nitrates nor in the other analytical results. From May 29, 1899, to Oct. 9, 1899, the application of sewage in doses was discontinued, and sewage was run on continuously through the grid until the surface was covered, the period of contact remaining unchanged. On Oct. 10, 1899, the method of operation was changed back so that the sewage was applied in seven doses one hour apart, with the filter standing full five hours. Beginning April 9, 1900, the filter was rested systematically every sixth week. At the end of 1900 the depth of the filter was 52 inches, about 2 inches of clogged material, resulting from an experiment upon the purification of wool liquor, having been removed from its surface and 6 inches in depth having been removed on Jan. 20, 1900. This latter removal was necessitated not entirely by clogging caused by the accumulation of organic matter, but largely by the disintegration of the somewhat soft and friable cinders of which the filter was constructed. Beginning Jan. 24, 1900, sewage that had first passed up through a tank containing pieces of scrap iron was applied, the idea being to cause the sewage to undergo anaerobic action before filtration, and thus to produce a better final effluent. As a result an effluent containing less organic matter than ever before was obtained for a few weeks. Much iron was carried in solution and in suspension upon and into the filter, however, which iron, by coating the cinders, finally caused an action similar to that occurring in contact filters containing iron, and to be discussed later in this report. As a consequence, nitrification practically ceased, and the rate of operation was materially reduced, owing to the clogging of the filter with precipitated iron. On May 20, 1900, untreated sewage was again applied, but not until August had enough iron been carried away from the filter to allow oxidation and nitrification to become again active.

On April 30, 1898, a third filter, No. 107, containing 2 feet in depth of screened cinders, was put into operation. This filter was flooded twice daily with regular station sewage, applied in one dose until the filter was full, allowed to stand full one and one-half hours and then drained rapidly, a period of one and one-half hours being allowed for draining the filter before the second filling was begun. From the start this filter was allowed to rest systematically every sixth week. Nitrification started in May, 1898, but the effluent never contained more than 1 part of nitrates, except on one or two occasions, when samples were taken immediately after a period of rest.

The period of operation, rates of operation and the average analyses of the effluents of these filters are shown by the following analyses: —

Effluent of Filter No. 81, Nov. 28, 1896, to Sept. 10, 1898.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
733,000	0.68	1.88	.20	.15	8.17	1.08	.0070	1.24	336,500
Effluent of Filter No. 82, Sept. 14, 1897, to Jan. 23, 1900.									
241,000	0.55	1.14	.16	.13	8.40*	1.08	.0226	1.09	316,500
Effluent from Iron Tank applied to Filter No. 82, Jan. 24 to May 19, 1900.									
-	-	1.74	.31	.13	6.43	-	-	2.59	843,800
Effluent of Filter No. 82, Jan. 24 to May 19, 1900.									
514,700	0.47	0.93	.24	.13	6.90	0.57	.0031	0.94	260,600
Effluent of Filter No. 82, May 20 to Dec. 31, 1900.									
391,600	1.14	1.54	.17	.13	11.00	0.77	.0068	1.30	538,100
Effluent of Filter No. 107, April 30, 1898, to Sept. 30, 1899.									
631,300	0.60	1.62	.22	-	6.13	0.56	.0268	1.60	437,200

Coke Contact Filters Nos. 108, 108A, 175 and 176 (operated at Rates of from 285,000 to 1,281,000 Gallons per Acre daily).

Filter No. 108, containing 2 feet in depth of pea-size coke, was put into operation April 20, 1898. Until Oct. 2, 1899, it was operated as a secondary filter, the effluent from Filter No. 107 being applied slowly in the forenoon. When the filter was filled it was allowed to stand full one hour and then drained slowly, this operation being repeated in the afternoon. During this period the filter was rested systematically every sixth week. Nitrification became established early in May and continued to increase, the effluent during the first nine months of 1899 being entirely stable and containing an average of over 1.5 parts nitrates per 100,000. On Oct. 2, 1899, the filter began to be operated with strained sewage applied in two doses one hour apart, the filter standing full three

hours before draining and being filled but once a day. From March 12, 1900, to May 30, 1900, the filter was filled twice daily, and the period of standing full was reduced from three hours to two hours. During the time strained sewage was applied systematic resting was discontinued. Nitrification continued to be active although the effluent was of somewhat poorer quality when the filter was filled twice daily than during the earlier period, when it was filled once a day only.

On June 1, 1900, the coke in Filter No. 108 was mixed with enough new coke, of a somewhat coarser grade, to make the depth of the filter 4 feet, this practically new filter being designated No. 108A. Until Aug. 10, 1900, this filter was filled twice daily with strained sewage, applied in two doses one hour apart and allowed to stand full two hours. Beginning Aug. 11, 1900, regular station sewage was applied, the filter being filled but once daily, in the same manner as previously. Systematic resting every sixth week was practiced from the time the filter was rebuilt until it was discontinued, at the end of the year. Nitrification was feeble for a few weeks after the change in the depth of the filter, but was quickly re-established and remained active throughout the remainder of the year.

Comparison of the Purification of Untreated Sewage and of Strained Sewage in Contact Filters.

On June 3, 1901, two filters were started to study comparatively the purification of untreated and strained sewage in filters operated under identical conditions. These filters, Nos. 175 and 176, still in operation, were constructed of 5 feet in depth of coke of such size that all would pass through a screen with a 1-inch mesh, 75 per cent. through a screen with a ½-inch mesh and none through a screen with a ¼-inch mesh. Strained sewage was applied to Filter No. 175 and regular station sewage to Filter No. 176. From June 3 to Oct. 1, 1901, the filters were flooded in four applications of sewage one hour apart, allowed to stand full two hours and then drained slowly. From October 1 to October 13 each was flooded in four applications one-half hour apart and allowed to stand full four hours before being drained. From Oct. 14 to Dec. 15, 1901, the filters were filled with sewage in one application, about forty-five minutes being taken to fill each filter, after which they stood full two hours before being drained. From Dec. 16, 1901, to Feb. 28, 1902, each filter was filled twice daily in the manner previously described. After March 1, 1902, the filters were filled only once daily. During the first year the filters were operated without resting, but after June 6, 1902, they were rested systematically every sixth week. Nitrification started somewhat earlier in the filter receiving untreated sewage. After

nitrification became established, the effluent from Filter No. 175, receiving the strained sewage, became more highly nitrified and of better quality than that from its companion filter; and this has continued to be the case throughout the period of seven and one-half years that the filters have been in operation. The changes in the methods of flooding appeared to make comparatively little difference in the degree of purification obtained by either filter. During the latter part of 1906 a steady deterioration in the quality of the effluent from Filter No. 176, which was receiving the raw sewage, was noted, and it was evident that the filter was being overworked. On Jan. 1, 1907, a change was made in the character of the sewage applied to this filter, settled sewage being used. This change failed to produce any beneficial effect, and the filter continued to deteriorate, producing an effluent during 1907 and 1908 in which the nitrates averaged only about 0.30 part per 100,000, and which was generally putrescible.

The average analyses of the effluents from these four coke filters are shown in the following tables, together with the rates and period of operation of each: —

Effluent of Filter No. 108, April 20, 1898, to Oct. 1, 1899.

[Parts per 100,000.]

Quantity Applied. — Gallon per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid.		Nitrates.	Nitrites.			
			Total.	In Solution.					
520,900	.47	0.67	0.12	-	1.24	.0124	0.94	5.78	216,300

Effluent of Filter No. 108, Oct. 2, 1899, to March 11, 1900.

284,800	.60	1.18	0.18	.09	1.48	.0080	1.13	7.18	189,500

Effluent of Filter No. 108, March 12, 1900, to May 30, 1900.

542,100	.40	0.78	0.09	.13	1.27	.0071	1.06	7.24	346,400

Effluent of Filter No. 108A, June 1, 1900, to Aug. 10, 1900.

1,281,600	.38	2.00	0.17	.07	0.58	.0101	1.15	12.78	365,800

Effluent of Filter No. 108A, Aug. 11, 1900, to Dec. 31, 1900.

548,900	.97	1.19	0.16	.10	1.95	.0075	1.12	11.07	690,000

Effluent of Filter No. 175.

[Parts per 100,000.]

DATE.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Kjeldahl Nitrogen.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1901,[1] . .	909,800	.52	1.6381	.1716	.1238	-	11.46	1.34	.0197	1.05	131,500
1902, . .	768,200	.56	1.3742	.1786	.1081	-	10.66	1.74	.0027	1.16	425,700
1903, . .	596,300	.47	0.6486	.1237	.0824	-	9.31	2.27	.0041	1.04	401,000
1904, . .	469,600	.63	0.9895	.2279	.1586	-	12.38	2.06	.0330	1.48	937,700
1905, . .	483,700	.60	0.8959	.1817	.1294	.3441	9.47	2.10	.0776	1.28	498,400
1906, . .	497,300	.64	1.2280	.2485	.1840	.4439	13.66	2.30	.0478	1.92	457,800
1907, . .	431,900	.78	1.3558	.3167	.2245	.6060	14.06	2.01	.0207	2.19	316,300
1908, . .	431,200	.65	1.0458	.2860	.2460	.5054	13.82	2.44	.0216	1.99	523,409
Average,	573,500	.61	1.1470	.2168	.1565	.4749	11.85	2.08	.0283	1.51	461,500

[1] Filter started June 3, 1901.

Effluent of Filter No. 176.

[Parts per 100,000.]

DATE.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Kjeldahl Nitrogen.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1901,[1] . .	849,400	0.55	1.7229	.1842	.1250	-	10.13	0.89	.0096	1.06	396,800
1902, . .	698,700	0.56	1.4526	.1856	.1115	-	9.44	0.66	.0024	1.20	429,600
1903, . .	579,800	0.57	1.0443	.1543	.1102	-	9.66	1.36	.0046	1.34	597,900
1904, . .	465,000	0.69	1.7394	.2550	.1798	-	11.82	0.98	.0199	1.62	631,500
1905, . .	454,700	0.68	1.4943	.2083	.1562	.4296	8.57	0.96	.0639	1.41	426,500
1906, . .	490,600	1.04	1.7767	.2417	.1904	.4675	13.80	0.65	.0164	1.90	308,000
1907, . .	357,500	1.02	1.5933	.3005	.2243	.5519	14.32	0.30	.0054	2.40	194,600
1908, . .	330,100	-	1.1000	.2469	.1993	.4773	14.14	0.31	.0048	1.93	281,100
Average,	582,000	0.73	1.4904	.2221	.1621	.4816	11.48	0.76	.0159	1.61	408,200

[1] Filter started June 3, 1901.

Solids in Effluent of Filter No. 175.

[Parts per 100,000.]

Date.	Unfiltered.			Filtered.		
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1902,[1]	53.0	13.3	39.7	51.8	12.2	39.2
1903,	49.9	14.4	35.5	46.3	11.5	34.8
1904,	55.5	18.3	37.2	52.9	16.5	36.4
1905,	45.1	15.7	29.4	42.3	13.8	28.5
1906,	55.3	15.6	39.7	50.5	13.7	36.8
Average,	51.8	15.5	36.3	48.7	13.5	35.2

Solids in Effluent of Filter No. 176.

Date.	Unfiltered.			Filtered.		
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1902,[1]	48.4	12.9	35.5	44.5	10.7	33.8
1903,	46.6	13.1	33.5	44.0	11.8	32.2
1904,	53.5	16.6	36.9	47.8	13.4	34.4
1905,	41.0	12.9	28.1	39.0	11.9	27.1
1906,	47.5	12.5	35.0	45.2	11.1	34.1
1907,	61.1	12.0	49.1	58.5	9.4	49.1
1908,	57.1	10.1	47.0	54.7	8.9	45.8
Average,	50.7	12.9	37.8	47.7	11.0	36.7

[1] June to December inclusive.

Coke Filters operated with Septic Sewage A.—Filters Nos. 103 and 251.

Two contact filters have been operated with the effluent from Septic Tank A, these being Filter No. 103, constructed of gas coke of such size that all the pieces would pass a screen with a ¼-inch mesh and practically all be retained on a screen with a ⅛-inch mesh, and Filter No. 251, constructed of hard metallurgical coke of a size between ½ inch and ⅛ inch.

Filter No. 103 was 5 feet in depth and was first put into operation on Feb. 28, 1898, septic sewage being applied at the start in eight doses at intervals of one hour, the filter being allowed to stand for two hours before draining. Nitrification became active in this filter early in May, or about two months after the filter was started, and the effluent became of as good quality as that from intermittent sand Filter No. 100, operated with the same sewage at a much lower rate. From June 12, 1899, to Sept. 25, 1899, the method of operating the filter was changed to correspond with that of the gravel filters operated from 1892 to 1896, the outlet of the filter remaining open all the time, and the sewage being applied in seven doses at intervals of one hour, the same rate being maintained as previously. On Sept. 26, 1899, operation as a contact

filter was resumed but the method of operation was changed, the filter being filled in three doses at intervals of one hour, allowed to stand full one hour and drained within a period of five hours, after which it was filled and drained again in the same manner. Up to the time this change was made, nitrification had been active within the filter and the effluent had been nonputrescible and generally of good quality. By filling the filter twice daily, practically the original rate of the filter was obtained, but nitrification decreased and the effluent became of much poorer quality. Beginning March 2, 1902, the plan was adopted of operating the filter for five weeks and then resting it one week. Under this treatment the quality of the effluent improved somewhat, although it did not reach the high standard of the earlier years of operation. The open space of the filter was gradually filling up, and in June, 1904, after nearly six and one-half years' operation, it had become so serious that the filter was discontinued. This loss of open space was caused in part by the accumulation of organic matter, but it was due also in a great measure to a breaking down or disintegration of the filter material.

On Aug. 1, 1904, Filter No. 251, containing 28 inches in depth of hard metallurgical coke, was started, to replace Filter No. 103. Septic sewage was applied to this filter in three equal doses at intervals of one hour, two hours being allowed to elapse after the application of the last dose before the outlet was opened, the filter being filled but once a day. Beginning Dec. 1, 1904, and continuing until Oct. 17, 1908, when the operation of the filter was discontinued, the filter was filled twice daily, the sewage being applied during December, 1904, in three doses at hourly intervals and after that time in one dose. Nitrification became established in December, 1904, and remained active until the filter was discontinued. The effluent from this filter, while rarely putrescible and comparing favorably with other contact effluents, never showed the high degree of purification shown by the effluent of Filter No. 103 in 1898. This result must be attributed largely to the practice of filling the filter twice daily, which practice caused a similar falling off in the quality of the effluent from Filter No. 103 when it was filled twice a day instead of once, as happened during the earlier years of its operation. During the first two and one-half years of its history this filter was operated without resting, and in 1907 had become badly clogged. After July 8, 1907, it was rested systematically every sixth week, with the result that the clogged condition was much relieved. An interesting feature in the life of this filter has been the presence of large numbers of worms, of a form similar to the ordinary earth worm, which made their home in the filtering material during the last two or three years

of its use, practically covering the surface when the filter was filled with sewage and returning below when it was drained. These worms must have played a considerable part, in conjunction with the other living organisms, in the working over of the organic matter stored in the filter.

Tables showing the average yearly analyses of the effluents from Filters Nos. 103 and 251 together with the rate and period of operation of each filter, follow. The average analysis of the septic sewage applied to them may be found on page 474.

Effluent of Filter No. 103.

[Parts per 100,000.]

DATE.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
				Albuminoid.						
			Free.	Total.	In Solution.		Nitrates.	Nitrites.		
1898,[1] . . .	805,000	.35	1.7400	.1038	-	10.53	1.80	.0056	0.62	44,100
1899, ...	666,800	.35	0.6139	.0964	-	7.02	2.30	.0040	0.79	60,200
1900, ...	620,800	.40	0.4305	.0726	.0621	8.85	2.67	.0086	0.63	94,500
1901, ...	577,900	.49	0.6217	.1097	.1007	10.69	2.70	.0108	0.82	54,600
1902, ...	803,600	.47	1.4021	.1480	.0915	11.15	1.15	.0098	1.05	221,000
1903, ...	788,500	.57	0.6022	.1241	.0984	9.57	1.24	.0065	1.07	365,200
1904, ...	492,200	.94	1.7233	.1955	.1272	11.22	0.25	.0022	1.47	288,800
Average, . .	679,200	.51	1.0191	.1214	.0960	9.86	1.78	.0066	0.92	156,300

[1] Filter started Feb. 28, 1898; stopped June, 1904.

Effluent of Filter No. 251.

[Parts per 100,000.]

DATE.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Kjeldahl Nitrogen.	Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
				Albuminoid.							
			Free.	Total.	In Solution.		Nitrates.	Nitrites.			
1904,[1] . .	585,400	.58	2.9678	.2739	.1928	.7195	0.23	.0090	1.98	11.37	943,000
1905, . .	687,200	.70	2.1415	.2294	.1830	.5460	0.51	.0057	1.72	8.07	613,000
1906, . .	775,400	.71	2.2544	.2991	.2171	.5602	0.81	.0200	2.35	12.38	415,500
1907, . .	608,700	.82	2.4667	.4275	.2918	.7848	1.24	.0164	3.16	13.57	482,100
1908, . .	464,200	.68	1.5050	.3160	.2396	.5720	1.64	.0169	2.44	13.16	627,600
Average,	614,200	.70	2.2671	.3092	.2249	.6365	0.89	.0136	2.33	11.71	616,200

[1] Filter started Aug. 1, 1904; discontinued Oct. 17, 1908.

Solids in Effluent of Filter No. 1[illegible].

[Parts per 100,000.]

Date.	Unfiltered. Total.	Unfiltered. Loss on Ignition.	Unfiltered. Fixed.	Filtered. Total.	Filtered. Loss on Ignition.	Filtered. Fixed.
1902,[1]	47.1	9.8	37.3	[illegible]	[illegible]	[illegible]
1903,	42.2	10.8	31.4	40.5	[illegible]	[illegible]
1904,	49.4	13.2	36.2	[illegible]	10.0	[illegible]
Average,	46.2	11.3	34.9	[illegible]	9.7	[illegible]

Solids in Effluent of Filter No. [illegible].

Date.	Unfiltered. Total.	Unfiltered. Loss on Ignition.	Unfiltered. Fixed.	Filtered. Total.	Filtered. Loss on Ignition.	Filtered. Fixed.
1904,[2]	44.8	15.8	29.0	[illegible]	[illegible]	[illegible]
1905,	37.1	13.4	23.7	[illegible]	[illegible]	[illegible]
1906,	48.9	15.2	33.7	[illegible]	[illegible]	[illegible]
Average,	43.6	14.8	28.8	[illegible]	[illegible]	[illegible]

[1] June to December inclusive. [2] [illegible]

Contact Filters operated with [illegible] and [illegible].

On Sept. 11, 19[illegible], a [illegible] a contact filter with [illegible] in which the sludge [illegible] filter, No. 15[illegible], [illegible] applied in four [illegible] the application of [illegible] [illegible] established in this filter and the effluent [illegible] The material of which the [illegible] in a contact filter [illegible] became clogged quickly [illegible] discontinued.

On March [illegible] filter No. [illegible] August [illegible]

almost immediately, and reached a maximum of over 5.0 parts nitrates per 100,000 within six weeks. On October 1, when the nitrates in the effluent were 5.37 parts per 100,000, the method of flooding the filter was changed back to that in use before August 15. Following this change nitrification decreased, and practically ceased by the middle of December, although the filter was within the station and protected from the weather.

The failure of Filter No. 154 to purify this sewage and the poor purification by Filter No. 167 (except during the period when the sewage was efficiently aerated before being applied to the filter) can be attributed only to the character of the sewage. The ready purification of this sewage after aeration is additional proof of the preventive action upon nitrification of the gases formed by over-septicization.[1]

The average analyses of the effluents from these filters and their rates of operation are shown in the following table. The analyses of Septic Sewage B are given on page 476.

Effluent of Filter No. 154.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid.		Nitrates.	Nitrites.			
			Total.	In Solution.					
569,200	1.01	5.18	.27	.14	0.30	.0234	1.49	10.91	356,700
Effluent of Filter No. 167.									
396,600	-	6.63	.39	.20	1.34	.0159	2.09	11.88	227,000

Coke and Glass Beads. — Filters Nos. 104 and 105.

In order to study the different action of rough and smooth material, two tube filters were started March 19, 1898, Filter No. 104 containing 5 feet in depth of small pieces of coke about the size of a pea and Filter No. 105 containing the same depth of glass beads of a similar size. These filters were filled with regular station sewage applied in three doses one hour apart and allowed to stand three hours before draining, being flooded but once daily. The open space in both filters was the same, so that the rates were identical and the operations parallel. Nitrification

[1] See also discussion of Filtration of Septic Sewage, page 480.

started in the coke filter within the first month, and was active throughout the period of nearly ten months during which the filters were operated. In the filter composed of glass beads, nitrification was more backward, and did not become established for over two months. It continued throughout the ensuing seven months, but the effluent never contained more than one-half as much nitrates as that from the coke filter, nor was this effluent ever of so satisfactory a quality. The average analyses of the effluents from these filters are shown in a following table.

Contact Filters constructed of Bricks and Roofing Slate.—Filters Nos. 173, 174 and 186.

One of the chief difficulties in the operation of contact filters is due to the accumulation of organic matter, which causes a continual reduction in the volume of sewage which may be treated on such filters. On June 4, 1901, two filters were started, to see if good results could be obtained with filters constructed in such a manner and of such material that little organic matter could be retained within them. Filter No. 173 was constructed of upright bricks placed one-half inch apart, while Filter No. 174 was constructed of roofing slates placed on end with half-inch spaces between each. By this arrangement the surfaces of the filter materials formed vertical planes and any suspended matter in the sewage would settle to the bottom of the filters, whence it would be removed, at least in part, during the draining of the filters. Both filters were 28 inches deep at the start, and were filled with regular station sewage in two doses one hour apart, being allowed to stand full two hours before draining. On October 10 the depth of each filter was increased to 52 inches by the addition of more material placed in the same manner, and the sewage required to fill the filters was divided into three doses applied at intervals of one hour. Neither filter was successful in producing good effluents; the suspended matter in the sewage accumulated at the bottom, anaerobic action ensued when the filters were filled with sewage and no nitrification occurred.

On Jan. 1, 1902, these filters were discontinued. The slate in Filter No. 174 was then removed, washed and replaced, this time, however, horizontally instead of vertically, with an open space about one-half inch high between each slate. The idea was to provide as much surface as possible for the accumulation of suspended matter under the most favorable conditions, a plan exactly opposite to that pursued with the preceding filters. This practically new filter, called No. 186, was operated like Filter No. 174, being filled with regular station sewage in

three doses one hour apart and allowed to stand two hours before draining. The plan of providing favorable conditions for the deposition of suspended matter was entirely successful and the filter lost open space rapidly. The effluent, however, was never of good quality. During May and June the anaerobic conditions noted with Filters Nos. 173 and 174 became strongly marked, and the filter was discontinued at the end of June.

Effluent of Filter No. 104.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid.		Nitrates.	Nitrites.			
			Total.	In Solution.					
788,400	.32	0.96	.09	-	1.18	.0185	0.48	7.29	80,900

Effluent of Filter No. 105.

788,400	.68	2.06	.17	-	0.51	.0090	1.07	7.73	191,900

Effluent of Filter No. 173.

400,000	Brown.	3.29	.36	-	0.05	.0057	2.57	10.21	383,000

Effluent of Filter No. 174.

775,000	Brown.	3.96	.39	-	0.02	.0004	2.82	10.21	380,000

Effluent of Filter No. 186.

797,900	.78	3.43	.29	.22	0.03	.0029	1.88	9.23	446,000

Contact Filters containing Iron. — Filters Nos. 121, 123, 125, 139 and 165.

Metallic iron and oxides of iron have been used in the purification of water and sewage, and many positive statements have been made with regard to their influence, but their action had been studied but little previous to the investigations made at the Lawrence Experiment Station in 1899 and 1900. These experiments, which were reported on pages 469 to 475 and pages 416 to 420, respectively, of the 1899 and

1900 reports, were made to determine whether iron could be successfully employed as a carrier of oxygen and thereby assist the bacterial purification, or whether a chemical purification could be produced which would, in a measure, be a substitute for bacterial processes. Five different contact filters containing iron in one form or another were operated.

Filter No. 121, containing 5 feet in depth of a mixture of one-third iron turnings and two-thirds coarse coke, was started March 29, 1899, and Filter No. 123, consisting of 4 feet in depth of iron turnings alone, was started May 4, 1899, the former being operated with septic sewage and the latter with regular station sewage. During the period of seven months in which these filters were operated nitrification did not become established in either filter, but, from the appearance and analyses of the effluents, it was evident that a considerable degree of purification had been accomplished.

In February, 1900, a third filter, No. 139, containing 5 feet in depth of a mixture of one-third iron turnings and two-thirds broken stone, was started. During the first two months this filter was operated as a contact filter, being filled and emptied twice daily, after which it was operated as an intermittent filter. During the contact period there was no nitrification within the filter, although a reduction occurred in the free ammonia of about 30 per cent., and the albuminoid ammonia and oxygen consumed were each reduced over 70 per cent. The change to intermittent filtration did not affect the establishment of nitrification in the filter, and the effluent, except that it contained less free ammonia, was of about the same quality as that previously noted. The experiments with these filters were discussed in the reports for 1899 and 1900 in part as follows: —

The results obtained with these filters yielded much information as to the effect of iron in sewage filtration. The action of iron within a filter apparently depends upon whether or not free oxygen is present. The first action of the iron is to absorb the oxygen dissolved in the sewage or in the air of the filter, after which it will appropriate the oxygen of the nitrates and nitrites, reducing them to ammonia. The fragments of iron quickly become covered with a coating of hydrated sesquioxide of iron, although whether oxygen in this coating is again given up, and plays any further part in the purification, or whether the porous coating prevents the metallic iron from exerting its reducing action, is not entirely proved by the study of these filters. When the effluents of the filters contain iron in solution in the form of protoxide (as was usually the case with Filter No. 123) we know that the air, at least that in the lower part of the filter, contains no oxygen, and nitrification is out of the question; and yet when this condition

three doses one hour apart and allowed to stand two hours before draining. The plan of providing favorable conditions for the deposition of suspended matter was entirely successful and the filter lost open space rapidly. The effluent, however, was never of good quality. During May and June the anaerobic conditions noted with Filters Nos. 173 and 174 became strongly marked, and the filter was discontinued at the end of June.

Effluent of Filter No. 104.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
738,400	.32	0.96	.09	-	1.18	.0185	0.48	7.29	80,900

Effluent of Filter No. 105.

738,400	.68	2.06	.17	-	0.51	.0090	1.07	7.75	191,900

Effluent of Filter No. 173.

400,000	Brown.	3.29	.36	-	0.05	.0057	2.57	10.21	282,000

Effluent of Filter No. 174.

775,000	Brown.	3.93	.39	-	0.02	.0004	2.82	10.21	350,000

Effluent of Filter No. 186.

797,900	.78	3.43	.29	.22	0.03	.0029	1.88	9.23	446,600

Contact Filters containing Iron. — Filters Nos. 121, 123, 125, 139 and 165.

Metallic iron and oxides of iron have been used in the purification of water and sewage, and many positive statements have been made with regard to their influence, but their action had been studied but little previous to the investigations made at the Lawrence Experiment Station in 1899 and 1900. These experiments, which were reported on pages 469 to 475 and pages 416 to 420, respectively, of the 1899 and

1900 reports, were made to determine whether iron could be successfully employed as a carrier of oxygen and thereby assist the bacterial purification, or whether a chemical purification could be produced which would, in a measure, be a substitute for bacterial processes. Five different contact filters containing iron in one form or another were operated.

Filter No. 121, containing 5 feet in depth of a mixture of one-third iron turnings and two-thirds coarse coke, was started March 29, 1899, and Filter No. 123, consisting of 4 feet in depth of iron turnings alone, was started May 4, 1899, the former being operated with septic sewage and the latter with regular station sewage. During the period of seven months in which these filters were operated nitrification did not become established in either filter, but, from the appearance and analyses of the effluents, it was evident that a considerable degree of purification had been accomplished.

In February, 1900, a third filter, No. 139, containing 5 feet in depth of a mixture of one-third iron turnings and two-thirds broken stone, was started. During the first two months this filter was operated as a contact filter, being filled and emptied twice daily, after which it was operated as an intermittent filter. During the contact period there was no nitrification within the filter, although a reduction occurred in the free ammonia of about 30 per cent., and the albuminoid ammonia and oxygen consumed were each reduced over 70 per cent. The change to intermittent filtration did not affect the establishment of nitrification in the filter, and the effluent, except that it contained less free ammonia, was of about the same quality as that previously noted. The experiments with these filters were discussed in the reports for 1899 and 1900 in part as follows: —

The results obtained with these filters yielded much information as to the effect of iron in sewage filtration. The action of iron within a filter apparently depends upon whether or not free oxygen is present. The first action of the iron is to absorb the oxygen dissolved in the sewage or in the air of the filter, after which it will appropriate the oxygen of the nitrates and nitrites, reducing them to ammonia. The fragments of iron quickly become covered with a coating of hydrated sesquioxide of iron, although whether oxygen in this coating is again given up, and plays any further part in the purification, or whether the porous coating prevents the metallic iron from exerting its reducing action, is not entirely proved by the study of these filters. When the effluents of the filters contain iron in solution in the form of protoxide (as was usually the case with Filter No. 123) we know that the air, at least that in the lower part of the filter, contains no oxygen, and nitrification is out of the question; and yet when this condition

exists a notable degree of purification is effected, as evidenced by the marked reduction in the oxygen consumed and the albuminoid ammonia. It is quite possible, in some cases at least, that nitrification may have occurred, the nitrates and nitrites being later reduced to ammonia, and this would explain the relatively high free ammonia in some samples. From the action of these filters it is apparent that iron is most efficient when disseminated through the filter material, and that filters composed entirely of fragments of iron exert such a strong reducing action that nitrification is either entirely prevented or the nitrates and nitrites are reduced as soon as they are formed. It is highly probable that the active agent in promoting the purification of sewage in such filters as these is the hydrated oxide of iron which forms on the surface of the iron fragments, and that under these conditions iron does act on sewage as it is known to act in many other cases where it is in contact with organic matter exposed to the air, that is, as a carrier of oxygen to hasten the process of oxidation. In the case of Filter No. 139 this hydrous oxide of iron apparently did not form to any extent, however, and the action of metallic iron seemed to predominate. The question naturally arises, if this be true, why not make a filter entirely of iron oxide, to obtain the maximum favorable effect of iron as an oxidizing agent. It was attempted to answer this question by filling a tank entirely with a natural iron ore, most closely allied to the rusty coating formed on the iron filings, namely, limonite or brown hematite, a hydrous sesquioxide of iron.

On May 22, 1899, Filter No. 125, containing 4½ feet in depth of brown hematite of an effective size of about 1.00 millimeter, was started. This filter was operated as an intermittent filter until August 1, after which it was operated as a contact filter, being filled twice daily with regular station sewage. While it was operated as an intermittent filter nitrification became active, and continued to increase after the mode of operation was changed. Owing to the fineness of the material, however, and the high rate of filtration obtained by filling the filter twice daily, this filter became badly clogged, nitrification became less active and it could be kept in operation only by frequent resting. After each resting, the effluent, on the reapplication of sewage, contained a considerable amount of iron in solution, showing that the hematite had been reduced by the organic matter in the absence of oxygen. In November the rate of the filter was reduced one-half by filling the filter only once daily, but this had little effect upon the already badly clogged filter, and early in 1900, 6 inches of clogged material was removed from the surface. From May 15 to July 29, 1900, the filter was operated as an intermittent filter. In July the filter had become again badly clogged, and was allowed to stand filled with sewage for two weeks. Small samples of

the effluent taken from day to day showed large amounts of ferrous iron, a proof of the oxidation of the organic matter by the iron ore. At the end of this period the filter was drained, and was found to be in such a condition that it could be operated successfully as a contact filter at practically the original rate. This showed a more complete removal of clogging by resting than had ever been obtained at the station up to this time, and was attributed at the time to the beneficial action of the oxide of iron; similar resting results, however, have since been obtained with clogged contact filters in which no iron was present. Following this treatment nitrification again became active and continued until the end of the year. By the end of 1900, however, the filter had again become so badly clogged that it could be operated only with great difficulty, and early in 1901 it was filled and allowed to stand for a week at a time before being drained, to study the effect of prolonged contact of sewage with iron oxides. The results obtained during this period confirmed those previously discussed but added little that was new.

Whether natural limonite would prove more effective than mixtures of coke or stone and iron, or coke or stone alone, as a material for contact filters, was not satisfactorily answered by Filter No. 125, and on Feb. 3, 1901, Filter No. 165, containing 5 feet in depth of a somewhat coarser grade of limonite, was started. This filter was operated with regular station sewage, being filled once daily. Nitrification became active in June and continued for some months. The material of which the filter was composed, while coarser than that used in No. 125, was still too fine for a contact filter, and in December began to show clogging. Nitrification fell off and in June, 1902, the clogging had become so serious and the effluent of such poor quality that the operation of the filter was discontinued. The results obtained with this filter did not differ materially from those obtained with filters composed of broken stone or similar materials.

As to the practicability of various forms of iron in sewage filters, it may be said that while the experiments are interesting, and while a certain advantage may be recognized in mixing this hydrated oxide of iron with sand in intermittent sewage filters, still the advantage does not appear to be great enough to justify the use of iron, either in the metallic or oxidized condition, in the construction of contact beds on a large scale.

The average analyses of the applied sewage and of the effluents from the five contact filters containing iron are shown in the following table: —

Septic Sewage A applied to Filter No. 121.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid.		Nitrates.	Nitrites.			
			Total.	In Solution.					
-	-	3.49	.24	.19	-	-	1.76	6.33	340,300
Effluent of Filter No. 121.									
429,000	.45	3.14	.07	-	0.00	.0002	0.59	6.03	126,900
Regular Station Sewage applied to Filter No. 123.									
-	-	3.33	.55	.24	-	-	3.72	7.58	2,049,600
Effluent of Filter No. 123.									
1,058,000	-	1.88	.11	-	0.01	.0036	0.79	7.32	380,500
Regular Station Sewage applied to Filter No. 125.									
-	-	4.12	.69	.31	-	-	4.48	8.37	2,598,300
Effluent of Filter No. 125.									
642,200	.39	1.08	.11	.09	1.87	.0284	0.81	8.16	215,500
Regular Station Sewage applied to Filter No. 139.									
-	-	3.30	.73	.27	-	-	4.27	6.12	2,523,500
Effluent of Filter No. 139.									
1,779,300	.58	2.86	.20	.11	0.01	.0031	1.19	6.16	479,100
Regular Sewage applied to Filter No. 165.									
-	-	4.36	.70	.32	-	-	4.10	9.60	1,686,400
Effluent of Filter No. 165.									
608,500	.60	1.86	.17	.12	.80	.0076	1.03	8.88	161,000

Experiments with Contact Filters at Andover.

During the year 1898 a system of sewers and a filtration area were constructed in Andover, Mass. As the conditions seemed to afford an opportunity to study certain processes of sewage purification with a sewage somewhat different from that used at the experiment station, a septic tank and two experimental filters $1/200$ of an acre in area were constructed. One of these filters contained $5\frac{1}{2}$ feet in depth of coke, most of which would pass through a sieve with a half-inch mesh. There was a considerable proportion of large pieces of coke, however, and the material was free from dust. This filter was put into operation July 10, 1899, at a rate of 860,000 gallons per acre daily, receiving septic sewage. The sewage was applied through a perforated grid upon the surface of the filter, until the filter was full, and after standing full two hours it was drained slowly. Nitrification not becoming established in the filter, on August 20 the sewage was divided into two doses applied one hour apart. The effluent continuing of poor quality, on November 18 it was decided to operate the filter as a sprinkling filter, and it was so operated throughout the winter. During this period there was no nitrification and the effluent did not contain dissolved oxygen. Beginning May 8, 1900, the filter was again operated for a few days as a contact filter, but, as the effluent continued to be practically unpurified, the rate was reduced to 100,000 gallons per acre daily and the filter operated as an intermittent filter for two weeks. The rate was then increased to 200,000 gallons per acre daily, and two weeks later it was again increased, to 400,000 gallons per acre daily. This was in warm weather, but even at these low rates nitrification did not occur. Beginning Aug. 21, 1900, and continuing until Oct. 15, 1901, the filter was again operated as a contact filter, a small amount of sand being mixed with the coke in the filter to see if this would furnish conditions favorable to nitrification. The sewage continued to pass through the filter practically without change, there was no nitrification within the filter, and the effluent did not contain dissolved oxygen at any time during this period. From Oct. 15, 1901, to June 30, 1902, untreated Andover sewage was applied. The change in the character of the sewage had little effect on the work of the filter, and, although some organic matter was removed from the applied sewage during its passage through the filter, little nitrification occurred, and the effluent continued to be of very poor quality.

On Sept. 12, 1900, a small filter, containing $4\frac{1}{2}$ feet in depth of coke of a somewhat finer but more uniform size than that in the large filter, was put into operation. This filter was also operated with septic sewage, being filled in three doses at intervals of one hour and allowed to stand

Septic Sewage A applied to Filter No. 121.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
-	-	3.49	.24	.19	-	-	1.76	6.33	340,300
Effluent of Filter No. 121.									
429,000	.45	3.14	.07	-	0.00	.0002	0.59	6.08	126,900
Regular Station Sewage applied to Filter No. 123.									
-	-	3.33	.55	.24	-	-	3.72	7.58	2,049,600
Effluent of Filter No. 123.									
1,058,000	-	1.88	.11	-	0.01	.0036	0.79	7.32	380,500
Regular Station Sewage applied to Filter No. 125.									
-	-	4.12	.69	.31	-	-	4.48	8.37	2,598,300
Effluent of Filter No. 125.									
642,200	.39	1.03	.11	.09	1.87	.0234	0.81	8.16	215,500
Regular Station Sewage applied to Filter No. 139.									
-	-	3.30	.73	.27	-	-	4.27	6.12	2,522,500
Effluent of Filter No. 139.									
1,779,300	.58	2.86	.20	.11	0.01	.0031	1.19	6.16	478,100
Regular Sewage applied to Filter No. 165.									
-	-	4.36	.70	.32	-	-	4.10	9.60	1,086,400
Effluent of Filter No. 165.									
608,500	.60	1.86	.17	.12	.80	.0076	1.03	8.88	181,000

Experiments with Contact Filters at Andover.

During the year 1898 a system of sewers and a filtration area were constructed in Andover, Mass. As the conditions seemed to afford an opportunity to study certain processes of sewage purification with a sewage somewhat different from that used at the experiment station, a septic tank and two experimental filters $\frac{1}{200}$ of an acre in area were constructed. One of these filters contained $5\frac{1}{2}$ feet in depth of coke, most of which would pass through a sieve with a half-inch mesh. There was a considerable proportion of large pieces of coke, however, and the material was free from dust. This filter was put into operation July 10, 1899, at a rate of 860,000 gallons per acre daily, receiving septic sewage. The sewage was applied through a perforated grid upon the surface of the filter, until the filter was full, and after standing full two hours it was drained slowly. Nitrification not becoming established in the filter, on August 20 the sewage was divided into two doses applied one hour apart. The effluent continuing of poor quality, on November 18 it was decided to operate the filter as a sprinkling filter, and it was so operated throughout the winter. During this period there was no nitrification and the effluent did not contain dissolved oxygen. Beginning May 8, 1900, the filter was again operated for a few days as a contact filter, but, as the effluent continued to be practically unpurified, the rate was reduced to 100,000 gallons per acre daily and the filter operated as an intermittent filter for two weeks. The rate was then increased to 200,000 gallons per acre daily, and two weeks later it was again increased, to 400,000 gallons per acre daily. This was in warm weather, but even at these low rates nitrification did not occur. Beginning Aug. 21, 1900, and continuing until Oct. 15, 1901, the filter was again operated as a contact filter, a small amount of sand being mixed with the coke in the filter to see if this would furnish conditions favorable to nitrification. The sewage continued to pass through the filter practically without change, there was no nitrification within the filter, and the effluent did not contain dissolved oxygen at any time during this period. From Oct. 15, 1901, to June 30, 1902, untreated Andover sewage was applied. The change in the character of the sewage had little effect on the work of the filter, and, although some organic matter was removed from the applied sewage during its passage through the filter, little nitrification occurred, and the effluent continued to be of very poor quality.

On Sept. 12, 1900, a small filter, containing $4\frac{1}{2}$ feet in depth of coke of a somewhat finer but more uniform size than that in the large filter, was put into operation. This filter was also operated with septic sewage, being filled in three doses at intervals of one hour and allowed to stand

Septic Sewage A applied to Filter No. 121.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
-	-	3.49	.24	.19	-	-	1.76	6.33	340,300
Effluent of Filter No. 121.									
429,000	.45	3.14	.07	-	0.00	.0002	0.59	6.08	126,900
Regular Station Sewage applied to Filter No. 123.									
-	-	3.33	.55	.24	-	-	3.72	7.58	2,049,600
Effluent of Filter No. 123.									
1,058,000	-	1.88	.11	-	0.01	.0036	0.79	7.32	380,500
Regular Station Sewage applied to Filter No. 125.									
-	-	4.12	.69	.31	-	-	4.48	8.37	2,593,300
Effluent of Filter No. 125.									
642,200	.39	1.03	.11	.09	1.87	.0284	0.81	8.16	215,500
Regular Station Sewage applied to Filter No. 139.									
-	-	3.30	.73	.27	-	-	4.27	6.12	2,523,500
Effluent of Filter No. 139.									
1,779,300	.58	2.86	.20	.11	0.01	.0031	1.19	6.16	478,100
Regular Sewage applied to Filter No. 165.									
-	-	4.36	.70	.32	-	-	4.10	9.60	1,686,400
Effluent of Filter No. 165.									
608,500	.60	1.86	.17	.12	.80	.0076	1.03	8.88	181,000

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During the year 1898 a system of sewers and a filtration area were constructed in Andover, Mass. As the conditions seemed to afford an opportunity to study certain processes of sewage purification with a sewage somewhat different from that used at the experiment station, a septic tank and two experimental filters $1/200$ of an acre in area were constructed. One of these filters contained $5\frac{1}{2}$ feet in depth of coke, most of which would pass through a sieve with a half-inch mesh. There was a considerable proportion of large pieces of coke, however, and the material was free from dust. This filter was put into operation July 10, 1899, at a rate of 860,000 gallons per acre daily, receiving septic sewage. The sewage was applied through a perforated grid upon the surface of the filter, until the filter was full, and after standing full two hours it was drained slowly. Nitrification not becoming established in the filter, on August 20 the sewage was divided into two doses applied one hour apart. The effluent continuing of poor quality, on November 18 it was decided to operate the filter as a sprinkling filter, and it was so operated throughout the winter. During this period there was no nitrification and the effluent did not contain dissolved oxygen. Beginning May 8, 1900, the filter was again operated for a few days as a contact filter, but, as the effluent continued to be practically unpurified, the rate was reduced to 100,000 gallons per acre daily and the filter operated as an intermittent filter for two weeks. The rate was then increased to 200,000 gallons per acre daily, and two weeks later it was again increased, to 400,000 gallons per acre daily. This was in warm weather, but even at these low rates nitrification did not occur. Beginning Aug. 21, 1900, and continuing until Oct. 15, 1901, the filter was again operated as a contact filter, a small amount of sand being mixed with the coke in the filter to see if this would furnish conditions favorable to nitrification. The sewage continued to pass through the filter practically without change, there was no nitrification within the filter, and the effluent did not contain dissolved oxygen at any time during this period. From Oct. 15, 1901, to June 30, 1902, untreated Andover sewage was applied. The change in the character of the sewage had little effect on the work of the filter, and, although some organic matter was removed from the applied sewage during its passage through the filter, little nitrification occurred, and the effluent continued to be of very poor quality.

On Sept. 12, 1900, a small filter, containing $4\frac{1}{2}$ feet in depth of coke of a somewhat finer but more uniform size than that in the large filter, was put into operation. This filter was also operated with septic sewage, being filled in three doses at intervals of one hour and allowed to stand

full two hours before draining. No better results were obtained with this filter than with the large coke filter. Beginning Jan. 1, 1901, the effluent from the large coke filter was applied to the small coke filter. The effluent from the large coke filter passed through the secondary filter practically without change, and nitrification did not occur to any extent. The installation of an aerator on June 20, by which gases in solution were liberated and oxygen absorbed by the sewage in its passage to the filter, a procedure which had proved beneficial with filters operated at the experiment station, failed to produce any improvement. On August 15 the small coke filter was flooded with untreated sewage, but the change in the character of the applied sewage failed to improve purification, the effluent continued to be of poor quality, and on Oct. 1, 1901, the filter was again turned into a secondary filter, receiving the effluent from the large coke filter, which, at this time, was being flooded with untreated Andover sewage. Following this change, nitrification at once became active within the filter, and the effluent continued to be of a satisfactory quality throughout the winter and up to the end of June, 1902, when the operation of the filter was discontinued.

The failure of these filters to purify properly the septic sewage must be explained by the character of the sewage itself. In constructing the sewerage system of the town of Andover all storm water was excluded, and, in consequence, the sewage which reached the filtration area was very strong. The volume of sewage flowing was then comparatively small; it was also practically twenty-four hours old when it entered the septic tank, and when it reached the experimental filters, after having been for twenty-four hours in the septic tank, it was in a condition very difficult to purify. While this septic sewage was purified to a considerable degree by an intermittent sand filter, it could not be purified to any appreciable extent in the coke contact filters. The reason for the poor purification of the septic sewage was that not enough oxygen was introduced by the methods of operation and aeration to enable nitrification to occur, even when the effluent from the first filter was passed through a second filter of the same kind. When, however, the stale Andover sewage was applied first to one contact filter and then to another, without having first been passed through the septic tank, nitrification occurred in the secondary filter although not in the primary filter. A full discussion of the difficulties in the purification of oversepticized sewage and the reasons therefor are given on page 482. The average analyses of the Andover sewage, of the effluent of the septic tank and of the effluents of these two filters during different periods are shown in the following table: —

Average Analyses of Andover Sewage and Effluents of Large and Small Coke Filters.

Andover Regular Sewage.

[Parts per 100,000.]

Period.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
Oct. 15, 1901-June 30, 1902.	-	-	3.03	1.58	.80	-	-	7.66	13.35	3,519,000
Andover Septic Sewage.										
July 10-Nov. 18, 1899, Aug. 21, 1901-Oct. 15, 1902.	-	-	7.73	0.67	.52	-	-	4.81	13.39	1,632,000
Effluent of the Large Coke Filter.										
Oct. 15, 1901-June 30, 1902.	380,000	0.60	4.66	0.38	.32	.08	.0053	2.14	6.66	397,000
July 10-Nov. 18, 1899, Aug. 21, 1900-Oct. 15, 1901.	681,300	0.80	6.34	0.49	.39	.03	.0008	3.33	13.93	766,000
Effluent of the Small Coke Filter.										
Sept. 12-Dec. 31, 1900,	650,000	0.73	6.71	0.45	.31	.04	.0008	2.24	9.99	486,000
Jan. 1-Aug. 15, 1901,	474,000	0.83	4.81	0.40	.25	.09	.0002	2.37	8.53	555,000
Aug. 15-Sept. 30, 1901,	390,000	1.35	4.68	0.37	.15	.01	.0000	2.40	11.67	60,000
Oct. 1, 1901-June 30, 1902.	350,000	0.49	2.45	0.24	.15	1.0	.0644	1.35	6.88	239,000

Double Contact Filtration.—Filters Nos. 163, 164, 180 and 237.

Six different contact filters have been operated as secondary filters, receiving the effluents from other contact filters. Of these, the operation of Filter No. 108, during the period when it received the effluent from Filter No. 107, is discussed on page 404, and the operation of the small coke filter at Andover, when operated with the effluent from the large coke filter, is discussed on page 420.

On Jan. 10, 1901, two filters were started, to study the refiltration of the effluent from Filter No. 137. Filter No. 163 was constructed of 4½ feet in depth of coke of such size that all would pass a ¾-inch screen and none would pass through a ¼-inch screen, while

Filter No. 164 contained a like depth of coke, free from dust, all of which would pass through a ¼-inch screen. Both filters were filled once daily, the effluent from No. 137 being applied in two doses one hour apart and the filters allowed to stand full two hours before draining. Active nitrification began in Filter No. 164, containing the finer coke, practically from the start, and during the period of six months that the filter was in operation its effluent was stable and much better purified than that from its companion filter, but the open space decreased more rapidly. Nitrification did not become established in Filter No. 163 until March; once established, however, the filter gave an effluent which compared favorably with the best single contact effluents, although not as good as obtained from Filters Nos. 103 and 175 when at their best. From Dec. 16, 1901, to March 25, 1902, the remainder of the effluent from Filter No. 137 was applied in the afternoon, this quantity being sufficient to fill the filter about one-third full. From March 26, 1902, to the time the filter was discontinued, at the end of June, 1902, the former practice of filling the filter only once daily was resumed, the effluent from No. 137 being applied in four doses instead of two, as before. These changes in operation had little effect upon the effluent of the filter with the exception that nitrification was slightly reduced for a short time after the filter began to be filled twice daily.

Filter No. 180, containing 2 feet in depth of broken stone, walnut size, was started Oct. 1, 1901, to treat the effluent from Filter No. 167. It was filled once daily in one application and allowed to stand full two hours before draining. At the time this filter was started the effluent from No. 167 contained nearly 5.0 parts of nitrates, and the work of nitrification, well begun in the primary filter, was continued in the secondary, the effluent from which averaged over 6.0 parts nitrates during its first month of operation. In December the nitrates in the effluent from the primary filter fell to less than 0.5 part, while the effluent from the secondary filter averaged nearly 1.5 parts, showing a nitrification within the secondary filter equivalent to about 1.0 part nitrates. This filter went out of operation at the end of December, after three months of service.

Filter No. 237, containing 5 feet in depth of clinker varying in size from three-fourths to one and three-fourths inches, was put into operation Jan. 1, 1904. The underdrains of this filter were open channels made of brick in order to prevent as far as possible the clogging which had been found to occur near the bottom of some of the contact filters previously operated. This filter has always been filled twice daily with the effluent from Filter No. 221, applied in one dose, and has been allowed to stand full two hours before draining. Previous to July 8,

1907, the filter was operated six days a week without rest, but after that date it was rested systematically every sixth week. Nitrification became established in March, 1904, and since that time the effluent has been fairly stable and well nitrified, although of inferior quality to that obtained from Filters Nos. 103 and 175 when at their best. During the period of three and one-half years in which the filter was operated without rest there was an accumulation of organic matter within the filter, resulting in a reduction in open space of about 25 per cent. With the introduction of systematic resting an immediate elimination of the stored matter began, and within six months the open space had been restored to practically its original volume. The effect of this elimination of organic matter was especially noticeable in the high percentage of nitrates in the effluent and in the amounts of total nitrogen which were larger in the effluent than in the applied sewage.

The results obtained with these filters are shown in the following tables: —

Effluent of Filter No. 137 applied to Filter No. 163.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid. Total.	Albuminoid. In Solution.	Nitrates.	Nitrites.			
-	.75	2.99	.33	.17	0.14	.0033	2.17	9.69	452,700

Effluent of Filter No. 163.

706,300	.61	1.34	.16	.10	1.61	.0110	1.06	9.58	390,300

Effluent of Filter No. 137 applied to Filter No. 164.

-	-	3.24	.32	.19	0.23	.0006	2.17	9.18	502,000

Effluent of Filter No. 164.

764,900	.59	1.05	.14	.10	2.17	.0162	0.94	8.24	210,300

Effluent of Filter No. 167 applied to Filter No. 180.

-	-	5.00	.38	.22	2.62	.0011	1.74	11.61	49,100

Effluent of Filter No. 180.

306,600	.77	3.74	.29	.20	3.16	.0410	1.41	11.55	43,950

Filter No. 164 contained a like depth of coke, free from dust, all of which would pass through a ¼-inch screen. Both filters were filled once daily, the effluent from No. 137 being applied in two doses one hour apart and the filters allowed to stand full two hours before draining. Active nitrification began in Filter No. 164, containing the finer coke, practically from the start, and during the period of six months that the filter was in operation its effluent was stable and much better purified than that from its companion filter, but the open space decreased more rapidly. Nitrification did not become established in Filter No. 163 until March; once established, however, the filter gave an effluent which compared favorably with the best single contact effluents, although not as good as obtained from Filters Nos. 103 and 175 when at their best. From Dec. 16, 1901, to March 25, 1902, the remainder of the effluent from Filter No. 137 was applied in the afternoon, this quantity being sufficient to fill the filter about one-third full. From March 26, 1902, to the time the filter was discontinued, at the end of June, 1902, the former practice of filling the filter only once daily was resumed, the effluent from No. 137 being applied in four doses instead of two, as before. These changes in operation had little effect upon the effluent of the filter with the exception that nitrification was slightly reduced for a short time after the filter began to be filled twice daily.

Filter No. 180, containing 2 feet in depth of broken stone, walnut size, was started Oct. 1, 1901, to treat the effluent from Filter No. 167. It was filled once daily in one application and allowed to stand full two hours before draining. At the time this filter was started the effluent from No. 167 contained nearly 5.0 parts of nitrates, and the work of nitrification, well begun in the primary filter, was continued in the secondary, the effluent from which averaged over 6.0 parts nitrates during its first month of operation. In December the nitrates in the effluent from the primary filter fell to less than 0.5 part, while the effluent from the secondary filter averaged nearly 1.5 parts, showing a nitrification within the secondary filter equivalent to about 1.0 part nitrates. This filter went out of operation at the end of December, after three months of service.

Filter No. 237, containing 5 feet in depth of clinker varying in size from three-fourths to one and three-fourths inches, was put into operation Jan. 1, 1904. The underdrains of this filter were open channels made of brick in order to prevent as far as possible the clogging which had been found to occur near the bottom of some of the contact filters previously operated. This filter has always been filled twice daily with the effluent from Filter No. 221, applied in one dose, and has been allowed to stand full two hours before draining. Previous to July 8,

1907, the filter was operated six days a week without rest, but after that date it was rested systematically every sixth week. Nitrification became established in March, 1904, and since that time the effluent has been fairly stable and well nitrified, although of inferior quality to that obtained from Filters Nos. 103 and 175 when at their best. During the period of three and one-half years in which the filter was operated without rest there was an accumulation of organic matter within the filter, resulting in a reduction in open space of about 25 per cent. With the introduction of systematic resting an immediate elimination of the stored matter began, and within six months the open space had been restored to practically its original volume. The effect of this elimination of organic matter was especially noticeable in the high percentage of nitrates in the effluent and in the amounts of total nitrogen which were larger in the effluent than in the applied sewage.

The results obtained with these filters are shown in the following tables: —

Effluent of Filter No. 137 applied to Filter No. 163.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
		Free.	Albuminoid.		Nitrates.	Nitrites.			
			Total.	In Solution.					
-	.75	2.99	.33	.17	0.14	.0033	2.17	9.69	452,700
Effluent of Filter No. 163.									
706,300	.61	1.34	.16	.10	1.61	.0110	1.06	9.58	390,300
Effluent of Filter No. 137 applied to Filter No. 164.									
-	-	3.24	.32	.19	0.23	.0006	2.17	9.18	502,000
Effluent of Filter No. 164.									
764,900	.59	1.05	.14	.10	2.17	.0162	0.94	8.24	210,300
Effluent of Filter No. 167 applied to Filter No. 180.									
-	-	5.00	.38	.22	2.62	.0011	1.74	11.61	49,100
Effluent of Filter No. 180.									
306,600	.77	3.74	.29	.20	3.16	.0410	1.41	11.55	43,950

Effluent of Filter No. 237.

[Parts per 100,000.]

Date.	Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Kjeldahl Nitrogen.	Nitrogen as —		Oxygen Consumed.	Chlorine.	Bacteria per Cubic Centimeter.
			Free.	Albuminoid.			Nitrates.	Nitrites.			
				Total.	In Solution.						
1904, . .	858,500	.67	1.1441	.2027	.1414	–	0.66	.0092	1.53	10.69	635,500
1905, . .	738,000	.68	0.7736	.1807	.1265	.3627	0.92	.0540	1.38	10.50	473,000
1906, . .	1,621,700	.64	1.0757	.2418	.1547	.4733	1.49	.0198	1.79	12.53	318,400
1907, . .	1,401,100	.72	1.2950	.3663	.1830	.6440	1.94	.0317	2.49	14.40	208,300
1908, . .	1,225,200	.75	0.7923	.3023	.1724	.5325	1.53	.0076	2.14	13.65	201,900
Average,	1,168,900	.69	1.0161	.2588	.1556	.5031	1.31	.0245	1.87	12.35	367,400

Solids in Effluent of Filter No. 237.

Date.	Unfiltered.			Filtered.		
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1904,[1]	42.2	12.6	29.6	40.2	11.0	29.2
1905, ...	41.8	12.6	29.2	39.2	11.2	28.0
1906, ...	52.5	15.5	37.0	45.2	10.9	34.3
Average, . . .	45.5	13.6	31.9	41.5	11.0	30.5

[1] October to December inclusive.

Summary and Conclusions of Contact Filtration. — Efficiency of Contact Filters.

In the foregoing chapters, the work of the various contact filters has been considered chiefly with reference to the quality of effluent produced. The main function of a sewage filter is to dispose of organic matter, but many of the contact filters described were operated for the purpose of studying special points of interest in the operation of filters of this kind and the results to be expected from such filters when constructed of different materials and when operated in varying ways.

Many of the filters were used for the study of specific problems and for short periods only, and their results are omitted from this discussion. Ten of the filters discussed were operated with untreated sewage, one of these being located at Andover and the other nine at the experiment station. The average removal of organic matter by the Lawrence contact filters was 68.8 per cent. as shown by the albuminoid ammonia

and 62.6 per cent. as shown by the oxygen consumed. The removal of albuminoid ammonia was over 70 per cent. for five different filters, and Filter No. 221 was the only one showing a removal of less than 60 per cent. The reduction in oxygen consumed was over 70 per cent. for three different filters; five others showed a reduction of between 50 and 70 per cent., while Filter No. 221 gave the poorest results, with a reduction in oxygen consumed of only about 46 per cent. The average reduction in free ammonia was 51 per cent., the highest reduction being 73 per cent. and the lowest 33 per cent. Three of the filters accomplished a reduction of over 60 per cent., while three others accomplished a reduction of less than 40 per cent. The average removal of bacteria was about 80 per cent., Filter No. 21A giving the best result, with a removal of nearly 92 per cent. Three other filters removed over 85 per cent. of the bacteria, and all showed an efficiency of 75 per cent. or over, except Filter No. 221, which removed only about 63 per cent. The greatest variation among the different filters was noticed in the degree of nitrification. The average oxidation by the nine Lawrence filters was about 15 per cent., the least being that by Filter No. 181, with an oxidation of only 2.4 per cent., and the greatest being that by Filter No. 108A which oxidized about 38 per cent. of the applied nitrogen. Oxidation in the large coke filter at Andover was poor, less than 1 per cent. of the nitrogen applied appearing in the effluent as nitrates and nitrites, and the reduction of free ammonia by this filter was less than that by any of the Lawrence filters operated with untreated sewage, except Filter No. 21A. In the removal of organic matter and of bacteria, however, the Andover filter compared favorably with the best of the filters operated with untreated sewage at the station. Of all these filters, Filter No. 108A accomplished the greatest amount of work, ranking highest in oxidation of organic matter and reduction of free ammonia, second in removal of albuminoid ammonia, third in removal of oxygen consumed and fourth in bacterial removal.

Two filters, Nos. 176 and 221, were operated with settled sewage after they had been previously operated with untreated sewage. Coke Filter No. 176 was more efficient than stone Filter No. 221 during both periods, but neither of these filters was as efficient, as shown by percentage removal of organic matter, when operated with settled sewage as when operated with untreated sewage, nor did they actually do as good work when receiving settled sewage as some of the filters operated with untreated sewage.

The average removal of albuminoid ammonia and of bacteria by the four filters operated with strained sewage was less than that of the filters operated with untreated sewage. In the reduction of free ammonia, the filters receiving strained sewage, however, were slightly more

efficient than the filters receiving untreated sewage; and in the oxidation of organic matter, they were much more efficient, the average oxidation of organic nitrogen by these four filters being 30.6 per cent., more than twice the average for the filters receiving untreated sewage. The greatest amount of oxidation was accomplished by Filter No. 175, which oxidized nearly 45 per cent. of the applied nitrogen. Filter No. 108 was second, with an oxidation of 36 per cent. of the applied nitrogen, a value only slightly less than that of No. 108A, the best of the filters receiving raw sewage.

Of the two filters operated with septic sewage A, Filter No. 103 was much more efficient than Filter No. 251, and was generally more efficient than the filters receiving raw sewage. The oxidation of organic matter by this filter was 38 per cent., that by Filter No. 251, 21 per cent.; the reduction in bacteria, organic matter and free ammonia by Filter No. 251 was only about one-half that accomplished by Filter No. 103. The two filters operated with septic sewage B, Nos. 154 and 167, were less efficient than Filter No. 103, operated with septic sewage A, although in some respects they did more work than Filter No. 251. Filter No. 167 accomplished the greatest amount of work of these two filters as regards oxidation of organic matter and reduction of free ammonia, but, judged by the removal of organic matter and of bacteria, Filter No. 154 gave slightly better results. The work of the two Andover filters when operated with septic sewage was generally unsatisfactory; the removal of organic matter was comparatively small and there was practically no oxidation of nitrogen.

Six secondary contact filters were operated. Of these, the work of Filter No. 237 and that of the small coke filter at Andover have been divided into two periods, according as the primary filters, with whose effluents they were operated, received treated or untreated sewage. The oxidation of nitrogen by some of these filters was especially notable. The greatest amount of oxidation was that by Filter No. 237 during the period when its primary filter was receiving untreated sewage, 68 per cent. of the applied nitrogen being oxidized. Filter No. 164 came second in this respect, with an oxidation of about 59 per cent. of the applied nitrogen. Filter No. 180 was the least effective of the secondary filters at the station, with an oxidation of less than 12 per cent., and the small coke filter at Andover when its primary filter received septic sewage, showed an oxidation of only about 1 per cent. As was to be expected with filters operated with a partly oxidized and clarified sewage, the percentage removal of organic matter by the secondary filters was much less than that by the various primary filters. The reduction of free ammonia, however, by the secondary filters, with the exception of Filter No. 180, was as a rule higher than that by the

primary filters, ranging from 47.5 per cent. to 67.6 per cent. An interesting feature in the work of Filter No. 237 was noticed during the second period of its operation, when it showed an oxidation of over 68 per cent. of the applied nitrogen, while at the same time the removal of albuminoid ammonia was only 3 per cent., and the amount of suspended matter in the effluent from the secondary filter was greater than that in the effluent of the primary filter. The great amount of oxidized nitrogen in the effluent from this filter, combined with the large amount of suspended matter, has been commented upon previously and will be discussed later. The work of the various filters is shown in the following table:—

Operated with Untreated Lawrence Sewage.

Filter Nos.	Per Cent. Reduction of — Ammonia. Free.	Albuminoid. Total.	Albuminoid. In Suspension.	Oxygen Consumed.	Bacteria per Cubic Centimeter.	Per Cent. of Applied Unoxidized Nitrogen Oxidized.
21A,	83.4	84.8	-	79.1	91.6	7.2
82,	64.2	73.2	91.7	68.9	84.9	23.1
107,	44.5	60.0	-	52.4	75.6	16.6
108A,	73.7	77.2	85.0	73.0	79.9	87.9
137,	88.8	57.0	65.0	50.2	78.6	9.4
165,	57.8	75.7	86.9	74.9	89.2	16.0
176,	64.5	71.0	85.3	65.2	79.9	18.8
181,	89.0	62.0	77.8	53.5	75.7	2.4
221,	46.7	58.0	75.0	45.3	63.3	3.4

Operated with Andover Untreated Sewage.

Andover large coke,	42.0	76.0	92.3	72.1	88.7	0.9

Operated with Settled Sewage.

176,	72.4	50.0	72.8	49.2	73.2	6.4
221,	46.4	37.7	59.2	36.1	46.8	2.9

Operated with Strained Sewage.

81,	42.9	48.7	50.0	36.0	72.3	27.2
108,	69.9	69.1	75.0	64.6	71.6	36.2
108A,	52.0	46.9	9.0	55.3	60.9	14.4
175,	73.1	58.5	70.0	54.4	76.5	44.5

Operated with Effluent from Septic Tank A.

Filter Nos.	Per Cent. Reduction of— Ammonia. Free.	Albuminoid. Total.	Albuminoid. In Suspension.	Oxygen Consumed.	Bacteria per Cubic Centimeter.	Per Cent. of Applied Unoxidized Nitrogen Oxidized.
103,	77.4	71.4	86.7	68.6	82.1	38.0
251,	46.2	29.5	40.0	31.0	34.5	21.0
Operated with Effluent from Septic Tank B.						
154,	28.1	66.2	76.0	70.4	84.0	4.3
167,	35.9	63.2	75.3	68.3	29.4	12.7
Operated with Andover Septic Sewage.						
Andover large coke,	18.0	26.8	33.3	30.8	53.1	0.04
Andover small coke,	9.4	29.6	39.0	42.7	73.6	0.55
Operated with Effluent from Filter No. 107.						
108,	58.7	45.5	–	41.3	50.5	37.4
Operated with Effluent from Filter No. 137.						
163,	55.2	51.5	62.5	51.2	13.9	47.2
164,	67.6	56.3	69.2	56.8	58.2	58.8
Operated with Effluent from Filter No. 167.						
180,	25.2	23.6	43.8	19.0	10.2	11.3
Operated with Effluent from Filter No. 221.						
237,[1]	53.0	27.5	0.0	29.2	18.8	39.3
237,[2]	56.2	3.0	–[3]	12.0	33.0	68.0
Operated with Effluent from Andover Large Coke Filter.						
Andover small coke,[4]	47.5	36.9	–[3]	37.0	39.8	21.5
Andover small coke,[5]	–[3]	–[3]	50.0	9.0	41.4	1.1

[1] Primary filter received untreated Lawrence sewage.
[2] Primary filter received settled Lawrence sewage.
[3] Ammonia higher in effluent than in applied.
[4] Primary filter received untreated Andover sewage.
[5] Primary filter received Andover septic sewage.

In the preceding discussion, the various contact filters have been treated as individuals. Each pair, consisting of a primary and secondary filter, may also be considered as a system, and the oxidation and removal values of each system may be computed. With the results from Filter No. 237 and the Andover small coke filter, divided into periods as previously explained, there are eight systems in all to compare. One of these, the system composed of the Andover large and small coke filters, when operated with Andover septic sewage may be omitted, as the results were entirely unsatisfactory. Of the remaining seven, the removal of organic matter varied between 43 and 84 per cent., judged by the albuminoid ammonia, and between 48 and 82 per cent., judged by the oxygen consumed. In the reduction of free ammonia there was less variation between the different systems, the greatest reduction being 78 per cent. and the smallest 67 per cent. The system composed of Filters Nos. 221 and 237, operated with settled sewage, was most efficient in this respect. The removal of bacteria by the different systems varied between 55 per cent. and 93 per cent., the combination of coke filters at Andover operated with untreated sewage being slightly more effective than that represented by Filters Nos. 137 and 164, which was the best of those at the experiment station. In the oxidation of nitrogen the variation was between 11 per cent. and 41 per cent., the Andover combination being the least efficient in this respect, and Filters Nos. 137 and 164 the most efficient. Generally speaking, the systems operated with untreated sewage did a greater amount of work, judged by the removal of organic matter and the oxidation of nitrogen, than did the systems operated with treated sewage. although such a comparison is perhaps not quite a fair one, since, of the three systems operated with treated sewage two were operated with very stale septic sewages, which proved very difficult to purify. Of the eight systems recorded, that represented by Filters Nos. 137 and 164 was the best from all viewpoints. This system ranked first in oxidation of nitrogen, second in removal of bacteria and of albuminoid ammonia, and third in the reduction of free ammonia and oxygen consumed. The Andover coke filter combination when operated with untreated sewage was in many respects nearly as good, ranking first in removal of bacteria, albuminoid ammonia and oxygen consumed. In the reduction of free ammonia, however, this combination was sixth, and in the oxidation of nitrogen it ranked seventh, and for this reason it is placed second to the Nos. 137–164 combination. The work of the various double filtration systems is shown in the following table: —

Double Contact Filtration Systems.

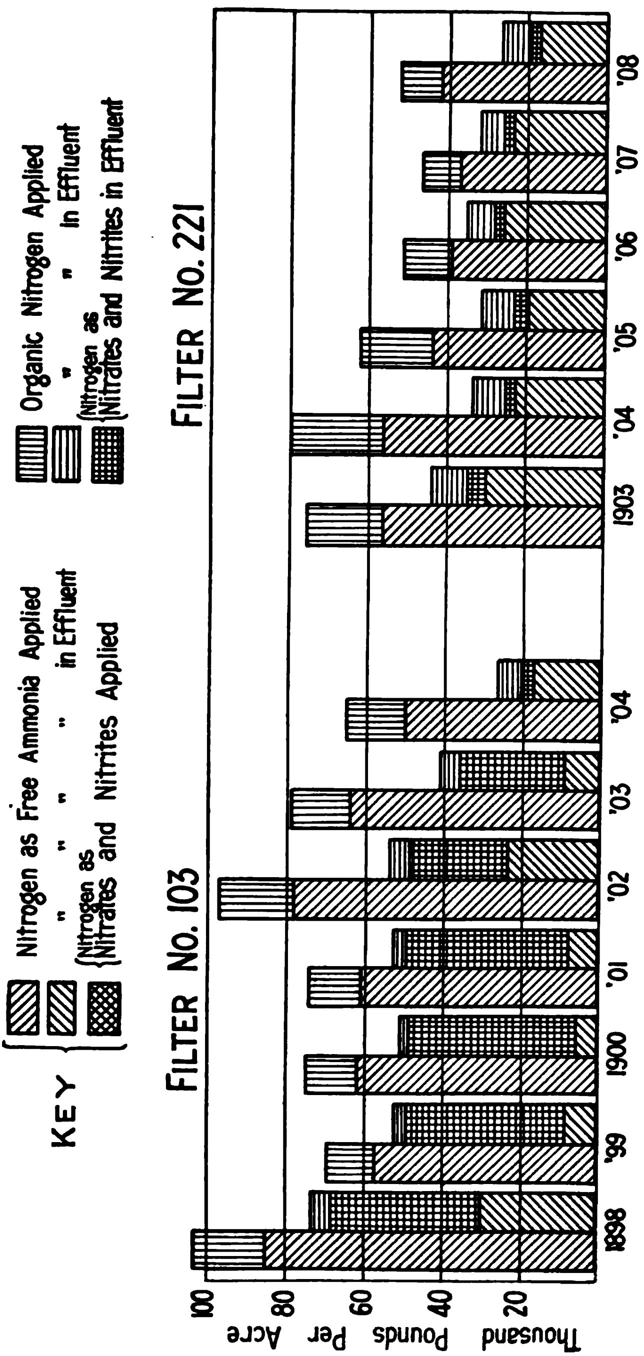
Operated with Untreated Lawrence Sewage.

Filter Nos.	Per Cent. Reduction of —					Per Cent. of Applied Unoxidised Nitrogen Oxidised.
	Ammonia.			Oxygen Consumed.	Bacteria per Cubic Centimeter.	
	Free.	Albuminoid.				
		Total.	In Suspension.			
107 and 108, . . .	77.1	78.2	-	72.0	88.0	35.3
137 and 163, . . .	69.5	77.2	84.2	74.4	77.8	32.0
137 and 164, . . .	76.9	81.8	90.0	80.5	90.6	41.1
221 and 237, . . .	75.8	71.2	75.8	68.4	71.3	21.7
Operated with Untreated Andover Sewage.						
Andover large and small coke filters, . . .	69.5	84.8	88.5	82.4	98.2	11.0
Operated with Settled Lawrence Sewage.						
221 and 237, . . .	78.1	43.4	61.3	48.4	67.0	24.6
Operated with Septic Sewage B.						
167 and 180, . . .	66.6	77.0	90.5	81.5	55.1	27.1
Operated with Andover Septic Sewage.						
Andover large and small coke filters, . . .	7.4	25.9	11.7	39.0	46.6	1.7

Comparative Disposal of Nitrogen by Principal Contact Filters.

In expressing the work performed by the various contact filters upon a percentage basis, the total amount of work which the filters were called upon to perform and the amount which they actually did perform is not shown clearly, since the high rate at which the filters were operated, especially when compared with the rates of sand filters, is not stated and does not enter into the computations. In Diagrams Nos. 17 and 18 are shown comparatively the yearly disposal of nitrogenous matter by six contact filters which have been operated for four years or more. In these diagrams the total amounts of nitrogen in the applied sewages and in the filter effluents are shown side by side, the blocks showing the total nitrogen being subdivided to show the amount of each of the various components of which that total nitrogen is made up. For purposes of

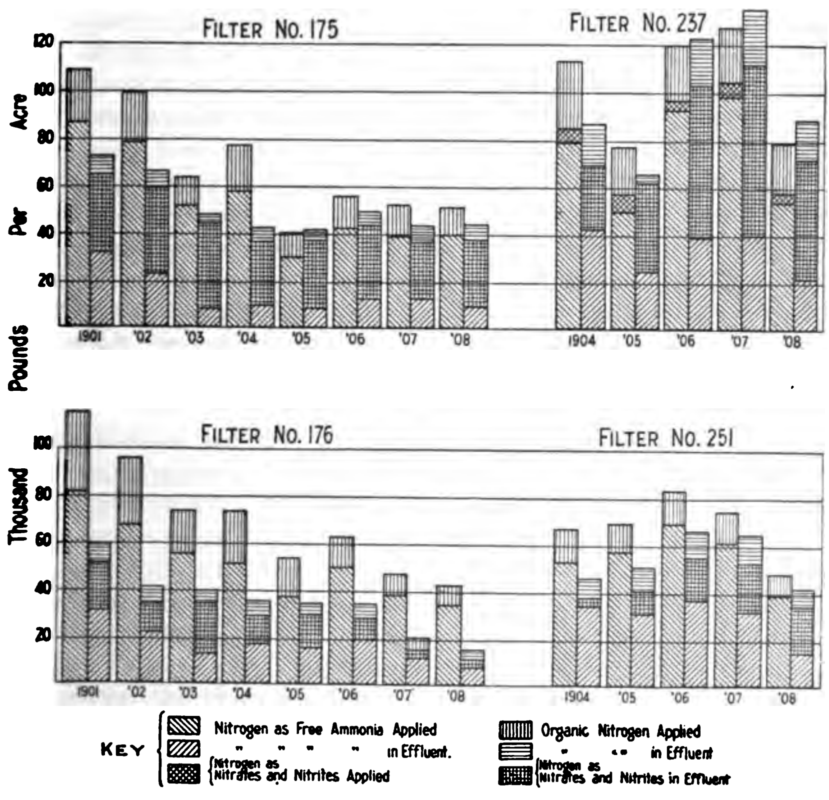
Diagram No. 17.



comparison, the values for the first calendar year have been computed as a full year, although some of the filters were operated for only a portion of the calendar year in which they were started. While this method of computation introduces some errors, which might have been avoided by a different arrangement of periods, it enables the results obtained with the various filters to be compared directly one with another and with the tables of analyses given previously. Many interesting features are to be noted in these diagrams. Filters Nos. 103, 175 and 176, containing 5 feet in depth of coke, were each receiving nitrogen in the beginning at the rate of over 100,000 pounds per acre per year. Filter No. 251, also of coke but only 28 inches deep, received less than 70,000 pounds per year, and Filter No. 221, of broken stone and 4½ feet in depth, could treat less than 80,000 pounds per year in the beginning. Owing to loss of open space, the amount of nitrogen which each of these filters could dispose of was considerably decreased as they were continued in operation. With Filter No. 103, after nearly four years of operation, an attempt was made to increase the amount of work by filling the filter twice a day, and this is apparent in the height of the column for 1902 and 1903. In 1904, however, the total nitrogen applied decreased to less than that in 1901, in spite of the two fillings a day. The effect of the double filling upon the nitrification is also very noticeable in the reduced amount of oxidized nitrogen in the effluent for 1902 and 1903, as compared with that of earlier years. A special feature in the work of this filter is the very small amount of nitrogen found as free ammonia and as unoxidized nitrogen in the effluent during 1900, when the filter was at its best. In the diagram for Filter No. 176 the same regular decrease in the amount of nitrogen treated is seen, and the small proportion of oxidized nitrogen in the effluent during 1907 and 1908, when the filter had become clogged, is noticeable. On the other hand, there stands out the large amount of oxidized nitrogen in the effluent from Filter No. 175, operated with strained sewage throughout the whole period. In the diagram for Filter No. 251 a steady increase in nitrification is noted from year to year, with a considerable increase when systematic resting was commenced. A greater proportion of the applied nitrogen is seen also in the effluent from this filter than was the case with any other primary filter. Filter No. 237 is the only secondary filter represented, and its diagram is distinctly different from those of the primary filters. The large amount of nitrogen which it received, and the extremely large amount oxidized, especially during the later years, is very noticeable; furthermore, the total nitrogen in the effluent was much greater than in the applied sewage during these years of excessive nitrification, showing elimination of

stored nitrogen from the filter. An amount of nitrogen in the effluent slightly greater than that in the applied sewage may be seen also in the diagram for Filter No. 175 in the year 1905. These diagrams were computed from yearly averages, and Filters Nos. 175 and 237 are the only filters which show elimination of nitrogen from the filter by the appearance of a greater amount of nitrogen in the effluent than was contained in the applied sewage. A careful examination of the ana-

Diagram No. 18.



lytical results, however, reveals the fact that all the filters, with the exception of Filter No. 221, showed similar phenomena at times. Computed from the monthly averages, the effluent from Filter No. 237 contained more nitrogen than the effluent from Filter No. 221, which was applied to it, 48 per cent. of the time, the effluent from Filter No. 251 contained more nitrogen than the septic sewage applied 18 per cent. of the time; while Filter No. 103, operated with the same sewage, showed elimination of nitrogen in this manner only 4 per cent. of the

time; Filter No. 175 receiving strained sewage, showed elimination of nitrogen 14 per cent. of the time, while its companion, No. 176, operated at first with raw sewage and later with settled sewage, showed similar phenomena only 2 per cent. of the time. These figures throw some light upon the storage of organic matter and the clogging of these filters, and the filters whose effluents contained more nitrogen than the sewage applied a considerable proportion of the time were found on examination to contain much less stored organic matter than did those in which the elimination of nitrogen was not indicated by the analytical results. From the analyses of the applied sewage and effluents and of the stored organic matters, the complete disposal of nitrogen by Filters Nos. 103, 175, 176, 221, 237 and 251 has been computed, and from these results much may be learned concerning the action of these filters. (See pages 435 and 436.)

If an estimate of the work of these filters be based upon the proportion of the total nitrogen applied which was oxidized, Filters Nos. 103, 175 and 237 are in a class by themselves, with oxidation values of 38, 45 and 47 per cent., respectively; Filters Nos. 176 and 251 form a second group, with values of 15 and 21 per cent., respectively; while Filter No. 221 falls far below, with only 3 per cent. oxidation. As regards liberation of nitrogen, however, the filters rank very differently, Filter No. 176 standing first, with a value of 49 per cent.; Filter No. 221, the poorest of the primary filters in oxidation, standing second, with a value of 42 per cent.; with Filters Nos. 103, 175 and 251 following in the order named, with liberation values of 35, 23 and 19 per cent., respectively, and Filter No. 237, the most active in nitrification, at the foot of the list, with a liberation of less than 0.1 per cent. In total amount of nitrogen disposed of there is less disparity among the various filters, although the results fall naturally into two groups, of which Filters Nos. 103, 175 and 176, with values of 74, 68 and 64 per cent., respectively, form one, and Filters Nos. 221, 237 and 251, with values of 45, 47 and 40 per cent., respectively, form the other. From this point of view the work of Filter No. 103 was exceptionally good, and it is interesting to note that the percentage of nitrogen oxidized and liberated by this filter was practically the same, showing that the reactions in the filter were perhaps better balanced than those in the other filters. Taking the disposal of organic nitrogen as a basis for comparison, however, the work of the filters assumes a somewhat different aspect. Inasmuch as it is not known exactly what becomes of the organic nitrogen, whether it is converted to free ammonia, oxidized or liberated, the computations must be based upon the amount of organic nitrogen in the applied sewage which cannot be accounted for either as organic nitrogen in the effluent or stored in the filter.

Since it is probably true that putrefaction can occur from organic nitrogen only, and that nitrogen as free ammonia, as nitrates and nitrites or as free nitrogen is innocuous as far as creating a nuisance is concerned, the disposal or mineralization of the organic nitrogen is, perhaps, the fairest criterion by which to judge the work of the various filters. Upon this basis the three filters, Nos. 103, 175 and 176, are in a group by themselves, with a disposal of 58, 54 and 56 per cent., respectively, of the applied organic nitrogen. As compared with these filters the work of Filters Nos. 237 and 251, with conversion values of only 18 per cent. and 15 per cent. respectively, were very poor indeed, while that of Filter No. 221, with a conversion value of 40 per cent., stands between the two groups. The low value for Filter No. 237 can perhaps be explained on the assumption that the organic matter applied had already been worked over in Filter No. 221 into a state in which it was not readily oxidizable, and that the action in the secondary filter was almost entirely aerobic, as is easily seen from the high nitrification. The low value for Filter No. 251, however, cannot be explained in this manner, nor can it be attributed to the fact that the sewage applied had undergone anaerobic action in the septic tanks, since Filter No. 103, which received a similar sewage, had the highest conversion value of any of the filters included in the comparison. The work of these six filters for their entire period of operation is shown in the following table: —

Comparative Disposal of Nitrogen by Principal Contact Filters.

	Filter Nos.					
	103.	175.	176.	221.	237.	251.
Period operated (years),	6.33	6.83	6.83	5.30	4.85	4.25
Pounds per Acre.						
In applied sewage: —						
As organic nitrogen,	97,000	117,000	119,000	78,000	111,300	54,000
As free ammonia,	415,000	369,000	362,000	245,000	358,300	236,000
Total,	512,000	486,000	481,000	323,000	469,600 [1]	290,000
In effluent: —						
As organic nitrogen,	28,000	51,000	47,500	39,400	89,500	42,000
As free ammonia,	94,000	101,000	118,500	128,500	158,400	127,000
As nitrates and nitrites,	195,000	218,000	74,000	10,600	219,700 [1]	61,000
Total,	317,000	370,000	240,000	178,500	467,600 [1]	230,000
Stored in filter: —						
As organic nitrogen,	12,677 [2]	2,292	4,552	7,307	1,602	3,620
As free ammonia,	809 [2]	785	118	858	85	199
Total,	13,486	3,077	4,670	8,165	1,687	3,819
Liberated,	181,514	112,923	236,330	136,335	313	56,181

[1] Not including oxidized nitrogen applied.

[2] Organic nitrogen estimated as 94 per cent. of total nitrogen stored.

Comparative Disposal of Nitrogen by Principal Contact Filters — Concluded.

Per Cent. of Organic Nitrogen applied.

	Filter Nos.					
	103.	175.	176.	221.	227.	251.
In effluent,	28.80	43.60	39.90	50.50	80.50	77.80
Stored in filter,	13.10	1.96	3.82	9.36	1.44	6.70
Mineralized or liberated,	58.10	54.44	56.28	40.14	18.06	15.50

Per Cent. of Total Unoxidized Nitrogen applied.

	103.	175.	176.	221.	227.	251.
In effluent: —						
As organic nitrogen,	5.46	10.50	9.88	12.20	19.00	14.50
As free ammonia,	18.35	20.70	24.60	39.70	33.60	43.70
As nitrates and nitrites,	38.10	45.00	15.35	3.30	46.90	21.00
Total,	61.91	76.20	49.83	55.20	99.50	79.20
Stored in filter,	2.63	0.63	0.97	2.58	0.36	1.38
Liberated,	35.46	23.20	49.10	42.10	0.07	19.40

Permanency of Contact Filters.

Next to giving good purification, the length of life or permanency of a sewage filter and the rate at which it can be operated are the most important considerations. With contact filters, operated upon the fill and empty principle, the open space in the material is of very great importance, since it limits the volume of sewage which can be purified, and all factors which influence that open space must receive careful consideration. In the operation of sand filters, where practically all suspended matters are retained at or near the surface, this deposit can, if necessary, be removed from time to time without disturbance of much of the filtering material. With filters of coarse material, however, the suspended matters enter into the main body of the filter, and one portion is as likely to be clogged as another. To maintain normal rates, and at the same time produce good qualitative results, experience at the station and elsewhere shows that it is advisable to remove a considerable portion of the suspended matter from a sewage before it is applied to a contact filter, thus preventing as far as possible the sludging up of the filter. The choice and grading of the material in a contact filter has considerable effect upon the initial open space and upon the freedom from clogging during operation. If materials are properly graded so that all particles are of similar size, the initial open space will be greater than if fine and coarse materials are mixed. Furthermore,

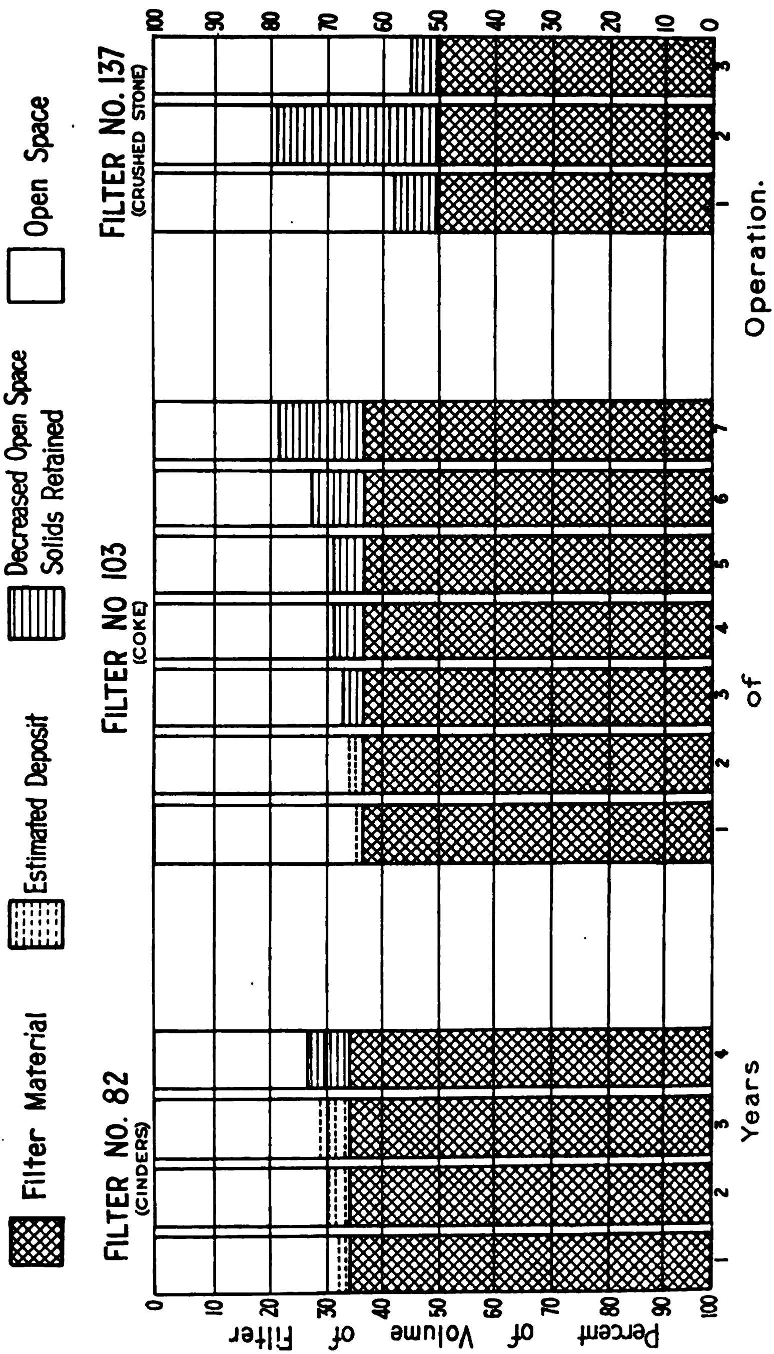
owing to the uniformity of the voids in a graded material the matters in suspension will pass more freely through the filter, and there will be less trouble from clogging. The filter material should also be of such nature that it will not break down in use, either through chemical agencies or under the weight of the superimposed layers. The disintegration of the material produces the same effect within the filter as the use of mixed sizes, that is, a reduction of open space and a liability to clogging. Many of these points were noted early in the investigations with contact filters, being discussed in the report for 1899, page 436, and in subsequent reports.

In Diagrams Nos. 19 and 20 the open space data on the principal contact filters up to the end of 1908 are shown graphically; the space occupied by various filter materials and by accumulated sludge and the average yearly open space, being expressed as percentages of the total cubic contents of the filter. By this method of statement the factor of differing depths of the various filters is eliminated; the relation of kind and size of material, accumulated sludge and period of service to the open space is clearly shown; and the plots for the various filters can be compared directly one with another.

The open space in the various filters at the start varied between 32 per cent. and 67 per cent., Filter No. 82, of cinders, having the lowest, and Filter No. 251, of hard coke, the greatest initial open space. There was a considerable variation in the initial open space in different filters constructed of similar material. For example, Filter No. 103 had only 37 per cent. open space; Filters Nos. 175 and 176 each had 59 per cent. open space, and Filter No. 251 had 67 per cent. open space, all of these filters being constructed of coke. The material in Filters Nos. 103, 175 and 176 was ordinary gas coke, which may have become broken more or less in handling. The low value for Filter No. 103 was undoubtedly due to the admixture of materials of varying sizes. Filter No. 251, on the other hand, was of hard metallurgical coke, which was very carefully screened and washed before being placed, with the result that a high degree of open space was obtained. Filters Nos. 137 and 221, both of carefully graded stone, but of somewhat different size, showed little difference in the initial open space. The broken stone, however, being smooth, packs much more closely than the coke, so that the initial open space was less than in the coke filters.

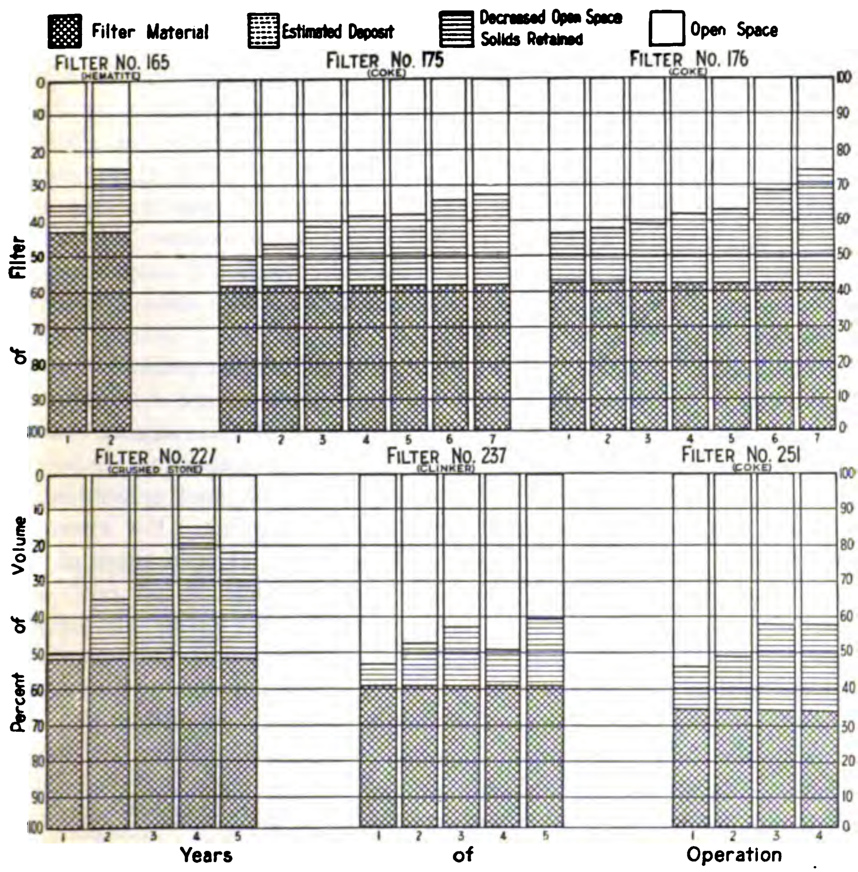
In practically all of the filters the reduction in open space was continuous when the method of operation was not modified. In Filter No. 103 the open space decreased from 37 per cent. to 20 per cent. during seven years of operation. In Filter No. 175, operated with strained sewage, the open space decreased from 59 per cent. to 47 per

Diagram No. 19.



cent. during the first two years, while in Filter No. 176, operated with **raw** sewage, the open space decreased from 59 per cent. to 43 per cent. during the same period. At the end of the third year of operation the open space in these two filters was practically the same, and at the end of the fourth year Filter No. 176 contained more open space than

Diagram No. 20.



did Filter No. 175. During the last two years of operation, however, the open space in Filter No. 176 decreased quite rapidly, the total open space at the end of the seventh year being only 26 per cent., as compared with 33 per cent. for its companion Filter No. 175. In Filter No. 221 the open space decreased from 53 per cent. to 15 per cent. during the first four years of operation. The introduction of systematic resting of this filter resulted in an increase in the open space to 22 per cent.

Similar results were obtained with Filter No. 251, which decreased in open space from 67 per cent. to 42 per cent. during the first three years of operation, further decrease being checked by systematic resting during the fourth year.

As a rule, the open space measurements on filters which were systematically rested were made after their period of rest, and the average yearly open space measurements are probably slightly too high for this reason. During 1908 measurements were made both before and after the resting periods, and from the results thus obtained the effect of resting on the volume of clogging material can be ascertained. In Filter No. 175 the volume of sewage which could be treated in the filter daily was increased 16 per cent. by a rest of one week. In Filter No. 176 the increase after resting was 23 per cent., in Filter No. 221, 41 per cent., and in Filter No. 251, 28 per cent. Filter No. 237 was the only one of the filters operated during 1908 which showed no increase in capacity due to resting, and, as previously explained, this is not surprising, as practically all the accumulated organic matter had been eliminated from this filter at this time.

The results with the different filters and at different periods of their service vary quite considerably as to the location of the clogging material within them. In some of the filters most of the clogging matter was found near the bottom; in others it was largely near the top, while in many cases a series of measurements extending over a number of years shows a change in the location of the clogging. For example, in Filter No. 103 in January, 1902, the per cent. of open space at the bottom of the filter was 27 per cent., in the middle 39 per cent. and in the upper foot 35 per cent. Two years later, the figures for the top and bottom were practically reversed, being 32 per cent. of open space at the bottom and 27 per cent. at the top, and the open space in the middle of the filter had decreased to 29 per cent. In Filter No. 175 during the first three years of operation the accumulation of stored matter was practically uniform throughout the material. In 1905, however, the bottom of the filter became quite badly clogged, although no reduction in the open space occurred in the upper layers. In 1906 the clogging of the lower layers had been quite largely eliminated, but the upper layers had been reduced in capacity. By the end of 1907 the lower layers had again become badly clogged. Similar results were noted with other filters.

Composition of Deposit in Contact Filters.

Numerous examinations have been made of the clogging material in different contact filters. As each filter was dismantled at the end of its period of operation, average samples were taken of all the material

in each, and results of analyses of these samples show the amount and composition of the deposit with a fair degree of accuracy. The analyses of the deposited matter show a general similarity, although there is more or less variation in the results from different filters and from the same filter at different times. The proportion of organic matter in the various samples averaged about 40 to 45 per cent. One sample from Filter No. 176 contained over 58 per cent. of organic matter, and one sample from Filter No. 237 showed as little as 35 per cent., but other samples from these filters were approximately between the limits stated. The fluctuation in the nitrogenous matter was somewhat greater, ranging between 1.5 per cent. and 3.5 per cent., although nearly all samples approximated the average of 2.5 per cent. quite closely. No regular fluctuation in the composition of the deposit is noticeable in the analyses, with the single exception of those obtained from Filter No. 176, in which an increase is noted in the loss on ignition, oxygen consumed and Kjeldahl nitrogen during the period between October, 1906, and April, 1908. Samples from other filters show variations in results obtained at the beginning and end of the same period, but the various organic matter determinations do not agree either as to increase or decrease. These fluctuations and the disagreement in amount of deposit can be attributed only to the method of obtaining the earlier samples. Typical analyses of the deposit in five of the contact filters are shown in the following table: —

Composition of Deposit in Contact Filters.

Filter Nos.	Date of Examination.	Pounds of Dry Sludge per Cubic Foot of Filter Material.	Per Cent. of Dry Sludge.					
			Mineral Matter.	Loss on Ignition.	Free Ammonia.	Kjeldahl Nitrogen.	Oxygen Consumed.	Fats.
175, . .	April, 1908,	0.36	60.4	39.6	1.21	2.92	12.00	1.19
176, . .	April, 1908,	0.60	41.6	58.4	0.11	3.48	12.60	1.96
221, . .	April, 1908,	2.35	57.8	42.2	0.18	3.08	12.50	1.97
237, . .	April, 1908,	0.49	64.8	35.2	0.10	1.94	9.44	1.03
251, . .	April, 1908,	1.54	54.8	45.2	0.43	2.82	11.80	1.89

Effect of operating Trickling Filters temporarily as Contact Filters, and Vice Versa.

It has been suggested occasionally that if the operation of trickling filters were interrupted by extreme winter weather, such filters might still be used for the disposal of sewage by operating them temporarily as contact filters. Three of the filters at the station which had been run as trickling filters have been changed to contact filters; one filter has been changed from trickling to contact and then back to trickling; and two filters, one at Andover and one at the station, have been changed from

contact to trickling and then back to contact; and from the results obtained with these filters we may get some idea as to the effect such changes will produce in the purification effected by such filters.

Filter No. 82, containing 5 feet in depth of cinders, was at first operated as a trickling filter. During this period nitrification became well established, and the nitrates in the effluent increased to over 2.0 parts per 100,000. After five months of such operation the filter began to be operated by the fill and empty, or contact, method, although the method of spraying the sewage upon the surface was not changed. One week after changing the method of operation the nitrates had dropped to 1.09 parts per 100,000, and one month later they had dropped to 0.16 part, and the effluent was of very poor quality. After this, however, nitrification became gradually re-established and the quality of the effluent improved, although the degree of purification did not reach the high value shown under trickling filter operation for over a year after the change was made.

Filter No. 103, containing 5 feet in depth of fine coke, had been operated about a year and a half as a contact filter with the effluent from Septic Tank A. During this period nitrification had become active and the effluent had become of extremely good quality, comparing favorably with that obtained from intermittent sand Filter No. 100, operated with the same sewage. From June 12, 1899, to Sept. 25, 1899, the method of operating this filter was changed, and the filter became essentially a trickling filter. The outlet remained open all the time, and the septic sewage was applied in small doses at frequent intervals throughout the day. On September 26 contact operation was resumed, and the filter was operated as in the beginning. As far as could be seen from the analytical results the change from contact to intermittent-continuous operation and back again produced no effect in the purification effected by the filter, nitrification continued to be active and the effluent was of uniformly good quality.

Filters Nos. 135 and 136, containing 17 feet 10 inches in depth of broken stone, were started Nov. 28, 1899, and operated as trickling filters until April 15, 1900. Early in 1900, after nitrification had begun, a profuse growth of Beggiatoa appeared, clogging both filters and preventing free access of air, with the result that nitrification ceased. and analyses showed the air within the filters to be practically devoid of oxygen. On April 16, Filter No. 135 began to be operated as a contact filter. The rate of trickling Filter No. 136 was decreased to only 100,000 gallons per acre daily, but even at this low rate nitrification did not become established. Nitrification had been somewhat better in contact Filter No. 135, the process of filling and emptying having caused a greater change of air within the filter. Analyses of air from

the two filters showed that the oxygen primarily present in the air within contact Filter No. 135 was only slightly decreased, while the air in trickling Filter No. 136 was composed mainly of nitrogen, being practically devoid of oxygen. On June 20 the depth of each filter was reduced to 10 feet. Following this change nitrification started immediately in trickling Filter No. 136, and in less than two weeks the nitrates in the effluent had increased to over 3.0 parts. Contact Filter No. 135, after the lessening of its depth, also gave a much better result than before, but did not by any means attain the efficiency of trickling Filter No. 136. On Jan. 1, 1901, Filter No. 135 was changed back to a trickling filter, and, after suitable provision had been made for proper circulation of air within the filtering material, nitrification became active.

On July 1, 1899, a filter containing 5 feet in depth of coke was started at Andover. This filter was operated with Andover septic sewage as a contact filter until Nov. 18, 1899, when the method of operation was changed, and the filter was operated as a trickling filter until May 8, 1900, when it was again changed back to the contact method. Nitrification did not become established in this filter until late in the fall of 1900, after a change in the character of the applied sewage had been made, and the effluent during the first and second periods was generally unsatisfactory. The failure of this filter to nitrify was due to the character of the applied sewage, and no noticeable change was produced by the changes in the method of operating the filter.

On Nov. 1, 1904, Filters Nos. 234 and 236, each containing 46 inches in depth of clinker, began to be operated as contact filters. These filters had been operated for ten months previously as trickling filters, nitrification had become well established and both were giving nonputrescible effluents. After changing to contact operation the effluents gradually became of poor quality, and after three months of such operation, nitrification practically ceased in both filters. During this same period, Filters Nos. 233 and 235, of the same materials as Filters Nos. 234 and 236, and which, prior to November 1, had been operated as companion filters to them, were continued in operation as trickling filters, without any deterioration in the quality of their effluents being noted.

The results obtained with Filters Nos. 82, 234 and 236 cannot but indicate that the reactions occurring in trickling filters are of an essentially different character from those in contact filters, and that a change in the method of operation from trickling to contact upsets the balance of the reactions occurring within the filters, and that a new balance does not become established for some months after the change in operation is made.

It is probable that the operation of a filter as a trickling filter in

summer and as a contact filter in winter would result in an effluent of much poorer quality during a large portion of the year than would be the case were the filter operated by one process all the time. The earlier results obtained with Filter No. 135, in which nitrification was apparently started by a change to the contact method of operation, must be considered abnormal, and can be attributed to the lack of proper ventilation, which condition would hardly be likely to occur in practice. The later results with this filter, when, after nitrification had become established under contact operation, the filter was changed back to a trickling filter, with still further increase in the nitrates, indicate that such a change might be beneficial in some cases.

Final Conclusions. — Contact Filtration.

From the experiments previously described it is evident that the nature of the material, the method of operation and the character of the applied sewage have very considerable effects upon the quality of the effluents from contact filters. The filters composed of coke or clinkers, that is to say, of rough material, gave at all times more satisfactory effluents than those composed of smooth material. From Filters Nos. 103 and 104 it was learned that the coke was far more satisfactory than a smooth hard material, such as glass beads. By a comparison of the results obtained with Filters Nos. 107, 175 and 176 of coke, with those of broken stone, Filters Nos. 137 and 221, it is readily seen that the coke was by far the more satisfactory.

This may have been due in part to the porosity of the coke which allows an absorption of the colloidal and soluble organic matter within the material itself when first started, resulting in a more satisfactory formation of a surface coating upon the material. Another effect of the rough material is to hold back the suspended matters and prevent their free passage towards the outlet of the filter. This is shown by the location of the clogging in different filters. In the coke filters this clogging is distributed quite uniformly throughout the filter, while in the filters of stone the greater part is in the lower portion of the filter. Experiments with brick and roofing slate showed that these materials, though more or less porous, as in the case of brick, were unsatisfactory when so arranged that the surfaces were vertical. The function of a sewage filter is to hold back the organic matter to allow time for the biological processes to take place, and this result was not accomplished with the brick and slate filters.

The material should also be of such character that it does not break down readily. This breaking down of the material has been commented on previously in a discussion of the results obtained with Filters Nos. 81, 82 and 103, the first two being constructed of cinders and the latter

of coke. The size of the material also plays a considerable part in the action of the filter. If the material is too coarse the voids are large and the sewage does not come intimately in contact with the surfaces. If, on the other hand, the material is too fine, clogging occurs, and the action within the filter becomes largely that of mechanical straining; moreover, putrefactive reactions abound, inasmuch as the entrance of oxygen is largely precluded. This action was very evident in the older filters of fine cinders, and was especially noticeable in Filter No. 103 towards the end of its history, when it had become clogged by the breaking down of the coke. The soft porous coke, however, was more effective apparently than the hard metallic coke, as Filter No. 251, although operated in the same manner and with a sewage of the same character as Filter No. 103, never produced an effluent up to the standard set by that filter.

The effect of iron and iron ore in contact filter materials has been discussed previously. The question as to the proper depth of contact filters appears to be one of engineering rather than of sanitary interest. According to the experiments at the station, the depth of material in a contact filter has very little relation to its biological activity. The difference in depth, however, does make a great difference in the volume of sewage which can be disposed of upon a given area. From this point of view deep beds are better than shallow ones.

The method of operating contact filters also has considerable effect upon the character of the effluent. If the filter be filled twice daily the resulting effluent will nearly always be less well purified than if the filter be filled only once daily. With Filters Nos. 175 and 176, this effect was not noticeable. With all the other filters operated at the station, however, in which both practices were followed, the nitrification was very much less when the filter was filled twice daily than when it was filled but once. This difference of action has been noted previously in the discussion of the results obtained from Filters Nos. 103, 107, 108, 137 and 221. The effect of filling a filter more than twice daily has been studied only during the short period when Filter No. 137 was filled three times a day. In this case the effluent was of even poorer quality than when the filter was being filled twice daily, and very much worse than when the same filter was operated with only one filling a day. The question of how long the sewage should remain within the filter has not been determined absolutely. The time may vary with different filters and with sewage of varying qualities. The contact periods for different filters have varied between 0 and five hours, and in a few instances the sewage has been allowed to remain in the same filter for different lengths of time. No marked difference has been noted in the character of the effluent due to changes in the time which the sewage stood in contact, however, with the exception of the one instance previously

noted, when an increase in the storage from three to five hours in Filter No. 82 resulted in a marked decrease in the amount of nitrates in the effluent.

Systematic resting of the filters for a period of one week in every six has proved to be beneficial in every case. Filters which operated without rest have become clogged, and in which nitrification has fallen off, have by the introduction of systematic resting been revivified. In the case of Filters Nos. 237 and 251 resting caused a marked reduction of the clogging and an elimination in the effluent of much of the stored organic matter in the form of nitrates.

The method of flooding contact filters at the station has been usually to apply the sewage in small doses at intervals of one-half to one hour apart, the number of doses varying from three to eight with different filters. With a few filters the sewage was run on the surface continuously until the filter was full, and with others the method of dosing was changed from time to time. So far as the quality of the effluent is concerned, however, the results show that little difference can be attributed to the method of applying the sewage. One effect of applying the sewage in doses, and one which should be considered when studying the results of filters so operated, is that caused by the fact that the first portions of the sewage applied remain in the filters for a much longer period than do the last portions. In some cases this difference amounts to five or six hours. Some differences in the clogging of contact filters also may be caused by variation in the method of flooding. If the sewage be sprinkled upon the surface, or applied in small doses intermittently, it will trickle slowly through the material, depositing the suspended matter as it proceeds, with little or no tendency to wash off the matters already deposited. Under such circumstances, the clogging material should be fairly evenly distributed, with the excess, if any, in the upper portions of the bed. The reactions taking place, furthermore, will be fairly uniform. If, on the other hand, the filter be flooded with a rush of sewage, the flow through the material will be much more rapid, and the tendency will be to form larger water-ways through which the suspended matter will be carried toward the bottom of the filter, and to wash off some of the matters which have been previously deposited. Under such circumstances the greater portion of the clogging will be found near the underdrains, the different levels in the bed will be working under different conditions and the reactions will be much more difficult to control.

The character of the applied sewage also plays an important part in the quality of the effluent. The best effluents and the best filter operation is secured when the applied sewage receives some preliminary treatment to remove suspended matters. This shows up quite plainly in the comparative results obtained with Filters Nos. 175 and 176, in which the filter operated with strained sewage gave an effluent which was at all

times more highly nitrified and more stable than that from the filter operated with untreated sewage. The fact that Filter No. 176, after it began to be operated with treated instead of untreated sewage, still gave a poorer effluent than that from Filter No. 175, cannot be considered as evidence that the strained sewage is more readily purified than the settled sewage, since Filter No. 176 had already become badly clogged, and conditions were less favorable than they would have been with a new filter. The effect of applying a treated sewage is of course mainly mechanical, that is, the clogging of the filter by suspended matters is prevented, but in preventing this clogging a considerable load is removed from the filter, in that these suspended matters do not have to be taken care of by biological processes.

The Comparative Disposition of Organic Matter by Sand, Contact and Trickling Filters.

The primary object of sewage purification is to change to a more stable form by bacterial action the matters in sewage which are easily subject to putrefaction, and thus to convert an ill-smelling, objectionable liquid into one free from odor and putrefying matters. Of the total organic matters present in sewage, however, only a small percentage is of the easily changeable, putrefying character. It is the large remainder of stable organic matter and mineral matter that causes most of the accumulation in settling tanks, clogs filters and becomes thereby one of the main elements of cost in adequate sewage disposal. In fact, it is now well recognized that in the successful treatment of large volumes of sewage the ultimate disposition of the matters in suspension present the chief difficulty. From 50 to 75 per cent. of the matter in Massachusetts sewage is organic, but only from 1 to 7 or 8 per cent. of this organic matter is nitrogen, — rarely more than 2½ per cent., — this percentage varying with the different sewages, and of course, at different times with the same sewage. The rest of the organic matter in sewage, or approximately 96 or 97 per cent. of that present, is carbonaceous, resistant to bacterial action and slow to purify or decay.

If we look at the filtration problem, then, from the point of view that successful purification is accomplished whenever the putrefying organic matter present in sewage is oxidized and rendered inoffensive, and the stable inoffensive organic matters are not retained by the filter, then the filter that will accomplish the greatest amount of this work upon the smallest area is the most successful one. If, on the other hand, we consider filtration successful only when practically all the organic matter present, both stable and unstable, has been removed from the sewage by the filter used, then a different problem is presented. Sand or other filters of a like material are the only ones that fulfil the latter

requirement, while contact and trickling filters under the best conditions of operation, can fulfil the first requirement.

Lawrence sewage as it reaches the experiment station is a strong domestic sewage, much stronger than the average sewage of American municipalities now operating purification plants, and contains an amount of matter in suspension fully equal and comparable with its strength in other respects. The matter in suspension is more or less finely divided, but not more so than in many sewages that have had a small amount of preliminary screening or sedimentation, or that have traveled through a considerable length of sewer before reaching the disposal area. The total amount of matter present in the average station sewage of the last twenty-one years has been about 2,800 pounds per 1,000,000 gallons, and the matters in suspension about 2,080 pounds per 1,000,000 gallons. This matter in suspension has had a composition about as follows: 70 per cent. organic or volatile matter and 30 per cent. mineral matter. The organic matter has averaged about 2.6 per cent. organic nitrogen, 40 per cent. carbon and 22 per cent. fat or fatty matters.

Filter No. 1 may be considered a typical intermittent sand filter. It has been operated during the past twenty-one years at an average rate of 68,300 gallons per acre daily, and the average effluent of this filter for the entire twenty-one years is as follows: —

Average Analysis of Effluent of Filter No. 1, 1888–1908, inclusive.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Temperature (Deg. F.). Sewage.	Temperature (Deg. F.). Effluent.	Color.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as — Nitrates.	Nitrogen as — Nitrites.	Oxygen Consumed.
68,300	57	54	.31	.7386	.0660	8.67	2.49	.0173	.60

This effluent has been practically free from matters in suspension, probably 95 of every 100 samples collected showing none, and the other 5 containing so little that it would be lost in averaging. Hence it may be assumed that practically none of the organic or mineral matter in suspension in the applied sewage has appeared in the effluent of this filter.

There has been applied with each 1,000,000 gallons of sewage about 375 pounds of nitrogen, and of this, about 18 per cent., or 67.5 pounds, has been organic nitrogen. Of the *total* nitrogen applied, including both that in solution and that in suspension, about 55 per cent. has been oxidized and has appeared in the effluent; about 18 per cent. has appeared in the effluent unoxidized; about 3 per cent. has been stored in

the filter, and 25 per cent. has been liberated and passed into the air. Of the *organic* nitrogen applied, consisting largely of the nitrogen of the suspended matters, about 65 per cent. has been oxidized, about 16 per cent. stored and about 19 per cent. has disappeared through the action of the nitrogen-liberating bacteria. The nitrogen in sewage, is, of course, a constituent of the organic matter which is liable to quick putrefaction, to the production of bad odors, etc., and is, therefore, the portion that must be broken up by bacterial action. It represents, however, as has been stated, but a small part of the total organic matter present. It is the nonputrefying, slowly decomposable organic matter and especially the organic matter in suspension that must be reckoned with finally. For instance, there has been applied to Filter No. 1, in each 1,000,000 gallons of sewage, about 2,800 pounds of organic matter, judging from loss on ignition results, and of this total about 2,100 pounds has been organic matter in suspension. As before stated, this matter was largely carbonaceous, inasmuch as the organic nitrogen formed but 3.3 per cent. of the total weight. Taking into consideration the rate of filtration, there has been applied to this filter about 62,000 pounds of organic matter *per acre* per year, and of this, 37,800 pounds has been organic matter in suspension in the sewage. There has accumulated in the filter about 10,500 pounds of organic matter *per acre* per year of service, and of this, only 2.5 per cent., or 262 pounds per year, is organic nitrogen. Of the total organic matter applied, 17 per cent. has accumulated in the filter, but as this accumulation has been largely caused by organic matter in suspension, the true comparison is with this, and of the 37,800 pounds of organic matter in suspension applied per acre per year, the analytical results show a storage of 28 per cent. Of this stored matter, 65 per cent. is found in the upper foot of filtering material, but there has not been enough stored up to the present time to prevent good operation of the filter and the production of a highly nitrified effluent. On account of the long period of storage and the resulting working over by bacterial action which most of it has had, the character of this organic matter has been changed materially. Of the matters in suspension in the applied sewage the fats are about 35 per cent. as great in amount as the loss on ignition, but in the stored matter the fats are only about 2.8 per cent. as great in amount as the loss on ignition. The amount of nitrogen in the suspended matter in the sewage has been about 6 per cent. as great as the amount of carbon, while in the stored matter it is about 2.5 per cent.

The results of this typical sand filter through many years of operation can be summarized as follows: At an average rate of about 70,000 gallons per acre daily, a rate requiring 14.3 acres per 1,000,000 gallons of sewage cared for per day, it has produced a clear, highly nitrified and

generally odorless effluent containing but a small percentage of the organic matter present in the applied sewage; it has disposed successfully of the nitrogen in solution in the applied sewage and 84 per cent. of the organic nitrogen. It has oxidized or otherwise successfully disposed of 72 per cent. of the total applied organic matter in suspension in the sewage and has stored 28 per cent. of this matter. The residuum of stored organic matter is almost unchangeable, and increases slowly but gradually as the filter is continued in use. It is probable, however, that the relative percentage stored will decrease and the percentage oxidized will increase as the filter continues in operation. That is to say, if this filter continues in operation for another ten years, the per cent. of the matters applied up to the end of that time that will have been stored will probably not be greater than 20, and the matters oxidized will have increased to 80, this being due to the fact that this comparatively stable matter does change slowly, and does show some relative decrease.

During the past fourteen years many contact filters have been operated at the station. For comparison the results of two of these filters, namely, Nos. 175 and 176, can be taken. These filters have been in operation eight years, and are constructed of coke. The average rate of operation of Filter No. 175 has been 573,500 gallons per acre daily and of Filter No. 176, 532,000 gallons per acre daily, these rates being eight or nine times as great as that of sand Filter No. 1; in other words, these filters have received in each year from eight to nine times as much sewage per unit area of surface as sand Filter No. 1. Filter No. 175 has always received strained sewage while Filter No. 176 received untreated sewage during the first six years and settled sewage the remainder of the time. The average analysis of the effluent of each of these filters for its period of operation is given here.

Effluent of Filter No. 175.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily for Six Days in a Week.	Color.	Ammonia.			Kjeldahl Nitrogen.	Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
			Albuminoid.							
		Free.	Total.	In Solution.			Nitrates.	Nitrites.		
573,500	.61	1.1470	.2168	.1565	.4749	11.85	2.08	.0288	1.51	461,500

Effluent of Filter No. 176.

532,000	.78	1.4904	.2221	.1621	.4816	11.48	0.76	.0159	1.61	408,200

There has been applied to Filter No. 175, with each 1,000,000 gallons of sewage, about 2,130 pounds of organic matter, and to Filter No. 176, 2,770 pounds; or, in other words, taking into consideration the rates of filtration, 400,000 pounds per acre per year have been applied to Filter No. 175 and 494,000 pounds to Filter No. 176, or from six to eight times as much per acre per year to these filters as to the sand filter previously discussed. Each 1,000,000 gallons of sewage applied to Filter No. 175 has contained on an average 800 pounds of suspended matter and each 1,000,000 gallons applied to Filter No. 176, 1,760 pounds, or 149,000 and 314,000 pounds per acre per year to Filters Nos. 175 and 176, respectively. Of the suspended matter, practically 75 per cent. has been organic, and Filter No. 175 has received 112,000 pounds of organic matter in suspension per acre per year, and Filter No. 176, 236,000 pounds. Filter No. 175 has received with each 1,000,000 gallons of sewage about 350 pounds of nitrogen, and of this about 23 per cent., or 80 pounds, has been organic nitrogen. The corresponding figures for Filter No. 176 are 390 and 78 pounds. Of the total nitrogen applied to Filters Nos. 175 and 176 there has appeared oxidized in the effluent of each 49 and 19 per cent., respectively; 2 and 1 per cent. of the total applied nitrogen has been stored, and 18 and 46 per cent. for each filter, respectively, has been liberated. Of the organic nitrogen applied to these filters, 6 per cent. has been stored in each. Of the total organic matter applied, Filter No. 175 has stored 5 per cent. and Filter No. 176, 6 per cent.; of the suspended solids in the sewage, they have stored 13 and 8 per cent., respectively, and of the organic matter in suspension applied, they have stored 17 and 10 per cent., respectively, or relatively, 60 and 36 per cent. as much as the sand filter mentioned. Of solids in suspension, Filter No. 175 has stored 19,400 pounds per acre per year and Filter No. 176, 25,000 pounds per acre per year. In other words, they have stored 100 and 135 pounds, respectively, of suspended matter for each 1,000,000 gallons of sewage applied, and of this stored matter 45 per cent. is organic. These filters have produced effluents of varying character, — effluents with much of the easily putrescible matter of the sewage oxidized or removed, and hence, generally, stable, notwithstanding the large amount of organic matter present. These filters require about 1.7 acres of surface per 1,000,000 gallons of sewage treated per day.

For a comparison of the results of sand and trickling filters, Filters Nos. 135 and 136 can be taken as being representative of the latter class. They are constructed of broken stone, and have received sewage at an average rate of 1,675,000 gallons per acre daily. With each 1,000,000 gallons of sewage there has been applied about 2,300 pounds of total organic matter and 875 pounds of organic matter in suspension,

or about 380,000 pounds of organic matter in suspension has been applied to each filter per acre per year. The filters have apparently stored 2 per cent. of the organic solids applied, 4 per cent. of the total suspended solids applied, and about 5½ per cent. of the organic matter in suspension in the applied sewage, that is, 21,000 pounds per acre per year, or about 50 pounds per 1,000,000 gallons of sewage applied. There has been applied with each 1,000,000 gallons of sewage, 375 pounds of nitrogen, and of this, about 17 per cent., or 64 pounds, has been organic nitrogen. To each filter there has been applied 28,000 pounds of organic nitrogen per acre per year, this organic nitrogen being about 7½ per cent. of the applied suspended solid matters. The filters have stored 1 per cent. of the total nitrogen applied and 6 per cent. of the organic nitrogen; 42 per cent. of the applied nitrogen has appeared oxidized in the effluent, 43 per cent. has appeared unoxidized, 14 per cent. has been liberated and 1 per cent. has been stored. The average analysis of the effluent of each of these filters for its period of operation is given below: —

Effluent of Filter No. 135.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily.[1]	Appearance.		Ammonia.			Kjeldahl Nitrogen.	Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
				Albuminoid.							
	Turbidity.	Color.	Free.	Total.	In Solution.			Nitrates.	Nitrites.		
1,542,300	4.5	0.69	1.6272	.2251	.1258	.3966	10.52	2.55	.0082	1.77	101,100

Effluent of Filter No. 136.

1,808,700	6.6	0.70	1.9880	.2716	.1575	.4837	10.58	2.21	.0107	2.06	71,500

[1] During 1899, 1900, 1901, 1902, and after April 8, 1906, these filters were operated seven days a week; during 1903, 1904, 1905, and the first three months of 1906, six days a week.

Summary.

The results of these filters, typical of the three classes now largely in use, show clearly their true function and action in handling the various kinds of organic and mineral matter applied to them. Oxidation of the matter which is actually putrefying at the time of application of the sewage is generally easily accomplished by any properly operated filter. A sand filter alone, however, strains sewage and removes from it all the matters in suspension. By straining and oxidation a good sand filter pro-

duces a clear, odorless and highly nitrified effluent. The rate at which such a filter can be operated is limited, however, and can rarely exceed 75,000 gallons per acre daily, if a normally strong sewage is applied and if filter permanence is desired. By preliminary treatments of the sewage this rate may be increased materially. Contact filters, as described, allow rates six to eight times as great as those of sand filters, but only the best contact filters give nonputrescible effluents. Trickling filters can be operated with normal sewage at rates at least three to four times as great as those of contact filters and twenty times as great as those of sand filters, with a production of highly nitrified, practically odorless and nonputrescible effluents. These effluents, however, are usually quite turbid, and should be, because the stable matters must pass through if the filter is to be permanent. That is to say, sand filters produce the clearest, most highly purified effluents, but retain much of the stable matters after oxidizing those which are unstable. Contact filters when well operated oxidize to a considerable extent the unstable matters, retain some of the stable matters, but pass a large part of these stable matters. Trickling filters, on the other hand, accomplish better oxidation than contact filters, and, owing to the nature of their construction and operation, allow the stable matters to pass through with the effluent. Sand filters, owing to their comparatively low rate of operation, take many years to accumulate enough stable organic matter to necessitate sand removal or cause difficulty in operation. The percentage of stable matters stored by trickling filters is slight, and apparently does not increase beyond a certain point, as shown by examinations of the filtering material. The peeling of the accumulated matter from the filtering material at times of bacterial activity, and its passage in large quantities into the effluent, has been frequently noted and commented upon in various reports. The average nitrates for the period of operation of the five filters discussed here are given below: —

Average Nitrates in the Effluents of Filters Nos. 1, 175, 176, 135 and 136.

[Parts per 100,000.]

Filter Nos.	Nitrates.	Filter Nos.	Nitrates.
1,	2.50	135,	2.55
175,	2.03	136,	2.21
176,	0.76		

or about 380,000 pounds of organic matter in suspension has been applied to each filter per acre per year. The filters have apparently stored 2 per cent. of the organic solids applied, 4 per cent. of the total suspended solids applied, and about 5½ per cent. of the organic matter in suspension in the applied sewage, that is, 21,000 pounds per acre per year, or about 50 pounds per 1,000,000 gallons of sewage applied. There has been applied with each 1,000,000 gallons of sewage, 375 pounds of nitrogen, and of this, about 17 per cent., or 64 pounds, has been organic nitrogen. To each filter there has been applied 28,000 pounds of organic nitrogen per acre per year, this organic nitrogen being about 7½ per cent. of the applied suspended solid matters. The filters have stored 1 per cent. of the total nitrogen applied and 6 per cent. of the organic nitrogen; 42 per cent. of the applied nitrogen has appeared oxidized in the effluent, 43 per cent. has appeared unoxidized, 14 per cent. has been liberated and 1 per cent. has been stored. The average analysis of the effluent of each of these filters for its period of operation is given below: —

Effluent of Filter No. 135.

[Parts per 100,000.]

Quantity Applied. — Gallons per Acre Daily.[1]	Appearance.		Ammonia.			Kjeldahl Nitrogen.	Chlorine.	Nitrogen as —		Oxygen Consumed.	Bacteria per Cubic Centimeter.
				Albuminoid.							
	Turbidity.	Color.	Free.	Total.	In Solution.			Nitrates.	Nitrites.		
1,542,300	4.5	0.69	1.6272	.2251	.1258	.3966	10.52	2.55	.0082	1.77	101,100

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1,	2.50	135,	2.55
175,	2.08	136,	2.21
176,	0.76		

PRELIMINARY TREATMENTS FOR THE REMOVAL OF SUSPENDED MATTER.

As frequently stated in preceding chapters on filtration of sewage, the volume of sewage which may be successfully purified upon a given filter area is inversely proportional to the amount of suspended matters in the sewage applied. In other words, if the whole or a part of the suspended matters are removed from the sewage by some treatment preliminary to filtration, the filters can be operated at much greater rates and a smaller area will be required for treatment of a given volume of sewage. All of the four different methods used for the preliminary clarification of sewage, chemical precipitation, sedimentation, straining, and septic tanks, have been studied extensively at the station during the last twenty-one years, and many filters have been operated with the sewage after it has been clarified by each of these processes as described in the previous chapters.

Settling Tanks.

During a period of six years, from 1892 to 1897, inclusive, experiments in regard to the amount of sludge that could be removed from Lawrence sewage by allowing it to stand for four hours were made. The results obtained in this investigation differed from year to year, according to the strength of the sewage and the amount of insoluble matters in suspension in it. An average of nearly 60 per cent. of the suspended matters as shown by the albuminoid ammonia in suspension was removed from the sewage by the process as carried out. In addition, about 33 per cent. of the total organic matter as shown by the albuminoid ammonia and 24 per cent. as shown by the oxygen consumed were removed, and about 27 per cent. of the bacteria were eliminated.

In August, 1906, a large settling tank was put into operation, in which the Lawrence sewage was clarified by sedimentation before being applied to a number of the contact and trickling filters at the station. In the earlier experiments upon sedimentation, just described, a uniform period of four hours was allowed for settling. Owing to the fact that settled sewage was applied to some of these filters throughout the twenty-four hours, while sewage was pumped into this tank only during the day, the actual period of sedimentation in this tank varied considerably, the minimum period being never less than two hours, while the maximum period was about fourteen hours. During the two and one-half years which this tank has been operated, the removal of matters in suspension has averaged about 44 per cent. as shown by the albuminoid ammonia in suspension, about 58 per cent. as shown by total solids, and 52 per cent. as shown by loss on ignition. The reduction of total

albuminoid ammonia and oxygen consumed has been 33 per cent. each, and the removal of bacteria has averaged about 31 per cent.

In addition to the experimental tanks in which the sedimentation of Lawrence sewage has been studied, the work of the settling tank which forms a part of the system of sewage disposal for the town of Andover has been carefully followed since 1903, and analyses of the sewage entering and leaving this tank have been given in the annual reports. The capacity of this tank is about 13,500 gallons. The volume of sewage entering the tank has varied greatly at different times, the average flow during the whole period being about 150,000 gallons per day. On this basis, the average period of sedimentation was about two hours. The average removal of suspended matter by this tank was about 56 per cent. as shown by determinations of albuminoid ammonia in suspension, 71 per cent. as shown by total solids, and 70 per cent. as shown by loss on ignition. The removal of total organic matter was about 32 per cent. as shown by albuminoid ammonia, 30 per cent. as shown by oxygen consumed, and about 51 per cent. of the bacteria were eliminated by the process.

The sludge accumulating in this tank is run upon sludge beds about once each month. Beginning in July, 1905, observations were made of the amount of dry sludge taken from these beds, together with analyses of this sludge. Up to November 15 sludge was removed from the sludge beds six times, the total dry weight amounting to about 20.5 tons. During this period of one hundred and eighty-five days, about 32,000,000 gallons of sewage passed through the settling tank, and about 1.25 tons of solid matter per million gallons of sewage were removed by the settling tank. — Report for 1905, p. 362.

During 1906 the weight of wet sludge, from April 23, when the winter's accumulation was taken from the sludge beds, until November 15, was 166,000 pounds. During this period the daily flow of sewage varied greatly, volumes as low as 75,000 gallons and as high as 350,000 gallons per day being measured. Assuming, however, that the average daily flow was 175,000 gallons, the figures show about 83.5 tons of wet sludge deposited, or about 4,560 pounds of wet sludge per million gallons of sewage. On drying, this sludge loses 61 per cent. by weight, and according to these figures there was deposited during the year about 1,800 pounds of dry matter per million gallons of sewage flowing through the tank. Analyses showed the dry sludge to contain 60 per cent. organic matter, 33 per cent. carbon, 1.6 per cent. organic nitrogen and 24 per cent. fat and fatty matters. — Report for 1906, p. 231.

The average analyses of the settled sewage as clarified by these various settling tanks are shown in the following table: —

Average Analyses of Effluents from Settling Tanks.

Tanks at Experiment Station.

[Parts per 100,000.]

Period.	Ammonia.				Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Albuminoid.					
	Free.	Total.	In Solution.	In Suspension.			
1896–1897,	3.86	.52	.33	.19	9.84	3.06	2,098,800
1906–1908,	4.76	.52	.30	.22	15.18	4.10	789,800

Tank at Andover Filtration Area.

Period.	Free.	Total.	In Solution.	In Suspension.	Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
1903–1908,	3.53	.58	.38	.20	6.23	3.43	1,567,000

Average Solids in Effluents from Settling Tanks.

Tank at Experiment Station.

[Parts per 100,000.]

Period.	Unfiltered.			Filtered.			In Suspension.		
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1906–1908,	62.4	21.3	41.1	54.9	15.6	39.3	7.5	5.7	1.8

Tank at Andover Filtration Area.

Period.	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1905–1908,	44.6	20.6	24.0	38.8	15.8	23.0	5.8	4.8	1.0

Chemical Precipitation.

Chemical precipitation was one of the earliest forms of modern sewage treatment and is still widely practiced abroad, both by itself and as a preliminary or preparatory process for further treatment. It is an efficient method of removing much of the suspended matters in sewage, and because of the resulting clarification high rates of filtration become practicable. It is an especially efficient preparatory process for the newer methods of filtration, as observed in the operation of contact and trickling filters.

In 1889 an extensive investigation was made at the station of the purification of sewage by chemical precipitation, in which data were obtained as to the relative efficiency of different chemicals, and it was shown how the precipitation process should be controlled to obtain the best results with the greatest economy of operation. These studies, which were summarized on pages 666 to 669 of the "Special Report on the Purification of Sewage and Water," 1890, and were described more completely in a special article on pages 737 to 791, inclusive, of the same report, were widely quoted by leading sanitary journals as an important contribution to the theory of chemical precipitation. The results of this investigation are best reviewed by quotations from the original report, as follows: —

If sewage is allowed to stand for a few hours, a portion of the organic matter will settle out; but the greater part is either too finely divided to separate in a moderate length of time, or is in solution. By adding certain chemicals to the sewage, an inorganic precipitate is formed, which settles rapidly and carries with it nearly all of the suspended matter, and also a portion of the dissolved matter. This is chemical precipitation of sewage. (Page 737.) From 25 to 43 per cent. of the soluble organic matter, as shown by the albuminoid ammonia and loss on ignition, was removed by copperas, ferric sulphate or alum. In addition to this, all of the suspended matter was removed. (Page 786.) Of the other substances present, the insoluble inorganic matters are removed almost completely, while the soluble salts, including chlorine and free ammonia, are not affected in the least, excepting that the acid of the precipitant remains in solution, in combination with the alkali of the sewage. A very large proportion of bacteria and of the other organisms is removed. This is all that can be done by chemical precipitation. (Page 787.) It is impossible to obtain effluents by chemical precipitation which will compare in organic purity with those obtained by intermittent filtration through sand. (Page 790.)

It is possible to remove from one-half to two-thirds of the organic matter of sewage by precipitation with a proper amount of an iron or aluminum salt, and it seems probable that, in some cases at least, if the process is carried out with the same care as is required in the purification of sewage by intermittent filtration, a result may be obtained which will effectually prevent a public nuisance. (Page 791.)

Using equal values of the different precipitants, applied under the most favorable conditions for each, upon the same sewage, the best results were obtained with ferric sulphate. Nearly as good results were obtained with copperas and lime, while lime or alum alone gave somewhat inferior effluents. When lime is used alone there is always so much left in solution that it is doubtful if its use would be satisfactory except in case of acid sewage. (Page 790.) It is quite possible that the same process would not give equally

good results upon all kinds of sewage. Special sewages may require special treatment. For this reason, and also on account of changes in the prices of the several chemicals, it is impossible to say that one precipitant is universally better than another. (Page 786.)

There is a certain definite amount of lime which gives a better result than less, and as good or better results than more. This amount of lime is that which exactly suffices to form normal carbonates with all the carbonic acid of the sewage. It is possible in a few minutes, by a simple titration, to determine approximately the amount of uncombined carbonic acid present in sewage, and how much lime will be required to combine with it. It is also possible to determine in a similar way whether enough or too much lime has been added. (Page 789.) By treating sewage with a large excess of lime, the undissolved calcium hydrate, in settling, carries down the insoluble organic matter almost completely, and in a very short time. (Page 747.) The action of smaller amounts of lime is quite different. Calcium carbonate is then formed with the carbonic acid of the sewage, and it is this carbonate instead of the hydrate which clarifies the sewage. Calcium carbonate is somewhat soluble in sewage containing carbonic acid. To obtain a precipitate, it is necessary to add enough lime to combine with the greater part of the carbonic acid. The amount of calcium carbonate precipitated can be computed in three ways: *First, from the alkalinity.* If we add the alkalinity of the sewage to that of the lime used, we obtain the total alkalinity of the mixture. As calcium carbonate precipitates, the alkalinity becomes less, and the decrease multiplied by 50, the equivalent weight of calcium carbonate, gives the amount of the precipitate. *Second, from the solids.* One ton of lime per 1,000,000 gallons is equal to 30 parts per 100,000 calcium carbonate. If we add the weight of the lime used to the fixed residue of the filtered sewage, and deduct the fixed residue of the precipitated sewage, we shall obtain the amount of the precipitate. *Third, from the carbonic acid.* The difference between the acid number[1] with phenolphthalein and the alkalinity represents one-half of the total carbonic acid, and the decrease in carbonic acid represents the calcium carbonate precipitated. These three processes give fairly concordant results, and are quite independent of each other, and the possible sources of error are entirely different. (Pages 748, 749.) The lime process has little to recommend it. Owing to the large amount of lime water required, and the difficulty of accurately adjusting the lime to the sewage, very close supervision would be required to obtain a good result, and even then the result is inferior to that obtained in other ways.

Precipitation with copperas is also somewhat complicated, owing to the necessity of getting the right amount of lime mixed with the sewage before adding the copperas. (Page 786.) Ordinary sewage is not sufficiently alkaline to precipitate copperas, and a small amount of lime must be added to obtain good results. The quantity of lime required depends upon the com-

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[1] The alkalinity is determined by titrating with twentieth normal sulphuric acid, using methyl orange as indicator; the acid number by a similar titration, using phenolphthalein as an indicator.

position of the sewage and the amount of copperas used, and can be calculated from a titration of the sewage. (Pages 789, 790.) When copperas is added to sewage alone, no precipitation takes place, and the result is no better than when sewage settles alone. The addition of enough lime to combine with the excess of carbonic acid over the amount required to form bicarbonates, and to combine with the sulphuric acid of the copperas, is necessary for precipitation; for, while sewage is alkaline, its alkali is all in the form of bicarbonate, and alkali as normal carbonate or hydrate is required to precipitate the iron. When this amount is added, the acid number with phenolphthalein will be zero. To insure a rapid action, a little more than this should be added. No better result is obtained when more lime is used. If much less is used, the iron will not be precipitated. (Page 764.) If enough or too much lime has been used the mixture will color phenolphthalein red, while if too little has been used no color will be produced. This test affords an easy and accurate method of applying enough lime and of avoiding an excess. Very imperfect results are obtained with too little lime, and the excess is wasted when too much is used. With a suitable amount of lime, the more copperas used the better the result; but with more than one-half a ton per 1,000,000 gallons, the improvement does not compare with the increased cost. (Page 790.) The amount of iron left in the effluent is much greater than with ferric sulphate, owing to the greater solubility of ferrous hydroxide. (Page 786.)

In precipitation by ferric sulphate and sulphate of alumina, the addition of lime is unnecessary, as ordinary sewage contains enough alkali to decompose these salts. (Page 790.) Ferric sulphate and alum have the advantage over both lime and copperas, that their addition in concentrated solution can be accurately controlled, and the success of the operation does not depend upon the accurate adjustment of lime or any chemical to the sewage. (Page 786.) Within reasonable limits the more of these precipitants used the better is the result, but with very large quantities the improvement does not compare with the increased cost. (Page 790.) The results with ferric sulphate have been, on the whole, more satisfactory than those with alum. This seems to be due in part to the greater rapidity with which precipitation takes place, and in part to the greater weight of the precipitate. It is probable, from the greater ease with which ferric sulphate is precipitated, that it would give a good result with a sewage that was not sufficiently alkaline to precipitate alum at once. (Page 786.)

In these experiments no account was taken of the character of the sludge produced with reference to its ultimate disposal. In a description in the report of the Board for 1893, of the treatment of the sewage from the fair grounds at Chicago during the World's Columbian Exposition,[1] the following statements concerning the sludge are made: —

[1] Hazen, "Chemical Precipitation of Sewage at the World's Columbian Exposition, Chicago 1893." Twenty-fifth annual report, Massachusetts State Board of Health, 1893, pp. 597-624.

The chemicals were added mainly in accordance with the principles given in the special report of the Massachusetts State Board of Health for 1890. . . . It was found that the sludge produced with copperas and lime as precipitants was much more easily pressed than that with alum, even when used with lime; and as the cost of pressing the sludge exceeded the cost of precipitating, copperas was a more economical precipitant than alum. For the same reason more lime was used with alum than was necessary to produce the best effluent, because the sludge produced in presence of an excess of lime could be more easily pressed, and the extra lime applied to the sewage was cheaper than the labor on the presses.

The chief results of the experiments on precipitation with different chemicals are shown in the following table. As the cost of chemical treatment has changed considerably since these results were first published, either through variation in price or by reason of improvement in quality, the cost of treatment at the present time as compared with the original cost in 1889 has been included in the table. These prices are based on the following quotations for chemicals delivered at Lawrence in large lots: Lime, containing 70 per cent. available CaO, $9 per ton in 1889 and $6 per ton in 1908. Copperas, containing 55 per cent. available $FeSO_4$, cost $10 per ton in 1889. Copperas of the same kind costs practically the same to-day, but for precipitation purposes a new iron salt, under the trade name of sugar sulphate of iron, containing 64 per cent. available $FeSO_4$, can be used with a reduction in cost of about 15 per cent. Crude alum, containing about 32 per cent. available $Al_2(SO_4)_3$, cost $25 per ton in 1889. At the present time sulphate of alumina for precipitation, containing 58 per cent. available $Al_2(SO_4)_3$, can be bought for $20 per ton, because of which the cost of precipitation is reduced more than one-half. Ferric sulphate, made by oxidizing copperas with sodium nitrate and sulphuric acid, cost about $24 per ton in 1889. At the present time, even with the somewhat richer sugar sulphate of iron, this salt would cost over $27 per ton, owing to the advance in the price of niter. The cost of precipitation would be thereby increased about 11 per cent.

Results of Precipitation of Sewage with Various Chemicals.

Precipitant.	Pounds per Million Gallons.		Per Cent. removed.			Cost of Chemicals.	
	A.	B.	Loss on Ignition.	Albuminoid Ammonia.	Bacteria.	1889.	1908.[1]
Plain sedimentation,	-	-	23	24	19	-	-
Lime,	-	800	35	43	67	$3 60	$2 40
	-	1,200	38	44	78	5 40	3 60
	-	1,600[2]	49	56	98	7 20	4 80
	-	2,000	48	56	98	9 00	6 00
Copperas,	500	-	26	21	10	2 50	2 15
	1,000	-	2	18	-	5 00	4 30
Copperas (A) and lime (B),	200	580[3]	21	37	95	3 61	2 60
	400	630[3]	26	41	98	4 33	3 61
	500	400	33	20	34	4 30	3 35
	500	700[3]	47	50	95	5 65	4 25
	500	1,200	43	65	99+	7 90	5 75
	500	2,000	47	56	99+	11 50	8 15
	1,000	800[3]	56	61	98	8 60	6 70
	2,000	1,100[3]	45	59	99+	14 95	11 90
Sulphate alumina,	500	-	37	38	97	6 25	2 75
	650	-	55	51	86	8 15	3 60
	870	-	49	56	91	10 90	4 80
	1,000	-	52	66	91	12 50	5 50
Sulphate alumina (A) and lime (B),	500	400	44	31	74	8 05	3 95
	500	800	39	47	91	9 85	5 15
	1,000	500	64	68	95	14 25	7 00
	1,000	1,000	60	67	99	17 00	8 50
	2,000	1,000	71	78	98+	21 50	11 50
Ferric sulphate,	500	-	29	48	86	6 00	6 80
	750	-	40	64	91	9 00	10 20
	1,000	-	61	67	97	12 00	13 60
Ferric sulphate (A) and lime (B),	500	400	42	60	78	7 80	8 00
	500	800	47	61	90	9 60	9 20
	1,000	500	62	70	96	14 25	15 10
	1,000	1,000	58	70	96	16 50	16 60

[1] For equivalent amounts.
[2] Amount adjusted to CO_2 in sewage.
[3] Amount adjusted to copperas.

In the experiments previously described, the period of sedimentation after the addition of chemicals was uniformly one hour. During five years, from 1893 to 1897, inclusive, a clarified sewage for use in two sand filters was prepared by treating regular sewage with sulphate of alumina in the proportion of 1,000 pounds per 1,000,000 gallons, and by allowing it to settle for four hours. The result of this treatment was an average removal of 56 per cent. of the total albuminoid ammonia, of 78 per cent. of the albuminoid ammonia in suspension, of 68 per cent. of the bacteria, a reduction of 59 per cent. in the fats and a 48 per cent. reduction in oxygen consumed. The removal of total organic matter in different years varied between 50 and 63 per cent. as shown by albuminoid ammonia, and between 38 and 53 per cent. as shown by oxygen consumed. The removal of suspended albuminoid ammonia varied between 72 per cent. and 83 per cent., the reduction in fats between 47 and 80 per cent., and the bacterial removal between 61 and 84 per cent. in the various years. The average analysis of the chemically precipitated sewage is shown in the following table:—

Average Analysis of Supernatant Sewage after Precipitation with Sulphate of Alumina.

Year.	Free Ammonia.	Albuminoid Ammonia.		Chlorine.	Oxygen Consumed.	Fats.	Bacteria per Cubic Centimeter.
		Total.	In Suspension.				
1893–1897, .	3.74	.34	.10	9.39	2.09	1.86	224,000

Clarification of Sewage by straining through Coke and Coal.

Coke Strainer A.—During 1894 various experiments were made to find the most suitable material that could be used as a strainer of sewage; that is, to simply remove from the sewage the matters in suspension without purification by nitrification, and with a removal from time to time of the straining material which had become clogged, together with the matters strained from the sewage. At this time the investigation seemed to show that coke was the most practical and effective material for the purpose, and a coke strainer was put in operation at the station, and sewage applied to it at the rate of 1,000,000 gallons per acre daily. This strainer contained at first 6 inches in depth of coke breeze, and the results obtained with it during the first year of its operation, in regard to the amount of organic matter removed from the sewage and the amount of coke used per 1,000,000 gallons of sewage strained, were given in the report of the Board for 1894. Approximately 48 per cent. of the organic matters were removed from the sewage during that year, with an expenditure of about 10 cubic yards of coke breeze per 1,000,000 gallons of sewage strained. On Nov. 26, 1895, the strainer was rebuilt with coke breeze of the character previously used, and from that

date until the last of September, 1898, a period of approximately three years, it was kept in operation at the rate given above. The depth of coke in the strainer varied at different times from 12 inches to about 3 inches. Whenever the shallower depth was reached, caused by removing clogged coke, all the coke remaining in the strainer was taken out, fresh coke filled in to the depth of 6 or 9 inches, and the 3 inches of old coke placed upon the top of the new coke. From Nov. 26, 1895, to Sept. 12, 1898, a volume of sewage equal to 1,180,000,000 gallons upon a surface of 1 acre had passed through this strainer, and 72 inches in depth of clogged coke had been removed; that is, 1 inch in depth of coke for every 16,400,000 gallons of sewage strained per acre, or 8 cubic yards of coke per 1,000,000 gallons of sewage strained. During this period coke had been removed on a number of occasions when the clogging was found to be due to the accumulation of fine coke dust in the underdrains, rather than to an accumulation of organic matter on the surface. In the beginning it was considered that the coke removed from the strainer would, when dried, be as valuable for purposes of combustion as before, and this was found to be true.

All the coke used until Oct. 1, 1898, was coke *breeze,* containing a mixture of pieces of coke of various sizes, together with coke dust. Upon this latter date, the strainer was again rebuilt of 15 inches in depth of small pieces of coke of the same grade as that in Filter No. 103 free from coke dust. From that date until Jan. 1, 1899, sewage equal in volume to 400,000,000 gallons upon an acre has been passed through the strainer without clogging it, and hence without the removal of any coke. For some weeks during the last part of 1898 the sewage was applied to the strainer at the rate of 2,000,000 gallons per acre daily, and this accounts in part for the smaller percentage of organic matter removed during these months than during 1899, when the rate was again 1,000,000 gallons per acre daily.

With the strainer of fine coke the surface was usually covered about twelve to fifteen hours per day when in good operation, and as the surface gradually clogged, this period increased until the maximum of twenty-four hours per day was reached, when the surface of the strainer was scraped. With the new strainer of coarser coke the surface is seldom covered more than four or five hours per day.

The percentage removal of organic matter was as follows: during 1895, 54 per cent. of the organic matter as represented by the albuminoid ammonia and 35 per cent. as represented by the oxygen consumed; during 1896, 47 per cent. and 49 per cent. respectively; during 1897, 62 per cent. and 50 per cent.; during 1898 up to October 1, 52 per cent. and 53 per cent. During the remainder of 1898 — that is, after rebuilding the strainer with coarser coke — the percentage removal was 32 per cent. and 37 per cent. respectively, and during 1899, 45 per cent. and 38 per cent. — Report for 1899, pp. 454–456 inclusive.

The coke strainer was continued during 1900 at an average rate of 1,000,000 gallons per acre daily. During its period of operation a volume of sewage equal to 720,000,000 gallons upon an acre was passed through it, and but 2

inches in depth of surface material had to be removed from it, or about 0.4 of a cubic yard per 1,000,000 gallons of sewage strained. During 1900 this strainer removed 44 per cent. of the organic matters in the sewage applied to it as shown by the albuminoid ammonia determinations, and 34 per cent. as shown by the determinations of oxygen consumed. — Report for 1900, p. 369.

The average removal of bacteria by the strainer of coke breeze was about 57 per cent., and that by the strainer of screened coke was about 72 per cent., in this respect the strainer of screened coke yielding a more satisfactory result. In removal of total organic matter and especially in removing the matters in suspension, which is the true function of a strainer of this character, the coke breeze strainer was much more effective. The average removal of suspended matter as shown by albuminoid ammonia in suspension was 74 per cent. during the period when the strainer was constructed of coke breeze and 59 per cent. when it was constructed of screened coke.

Bituminous Coal Strainer C. — On Sept. 12, 1898, a strainer containing 12 inches in depth of fine bituminous coal was put into operation, at a rate of one million gallons per acre daily, at which rate it continued to be operated until it was stopped at the end of 1900. This strainer was operated in the same manner as were the coke strainers previously described, being scraped when the accumulation of organic matter upon the surface prevented the passage of the required volume of sewage daily. The depth of the strainer varied from 12 inches to about 4 inches at different times.

During 1899 this strainer removed 57 per cent. of the organic matter of the sewage as represented by the albuminoid ammonia, and 36 per cent. of that represented by the oxygen consumed. From the date of starting up to the end of December, 1899, 8 inches in depth of coal had become clogged and removed, equal to 2.8 cubic yards per 1,000,000 gallons of sewage strained. — Report for 1899, p. 460.

During 1900 the strainer of fine bituminous coal removed 41 per cent. of the organic matter in the applied sewage as shown by the albuminoid ammonia determinations, and 34 per cent. as shown by the oxygen consumed. During the year one inch of coal was removed, equal to 0.8 cubic yard per 1,000,000 gallons of sewage strained. — Report for 1900, p. 370.

The average removal of bacteria by this strainer during its entire period of operation was about 70 per cent., and the removal of suspended matter as shown by the albuminoid ammonia in suspension was about 65 per cent. The average analysis of the effluent from this strainer is shown in a following table.

Anthracite Coal Strainers E and F. — During 1901 two new coal strainers, E and F, were put into operation. Each contained 12 inches in depth of buckwheat coal of such size that all would pass through a screen of one-half inch mesh and practically none through a screen with a one-eighth inch mesh.

Owing to the greater specific gravity of this material, it does not have the same tendency to float that coke has, and for this reason a large proportion of the matters removed from the sewage remain nearer the surface of the strainer than is the case with coke, and generally less of the straining material has to be removed when accumulations of organic matter are removed from its surface. One of the reasons for the use of such materials as coke or coal for the straining of sewage is that in operating any such strainer at a high rate it is assumed that a portion of the material of which the strainer is composed will probably have to be removed when the organic matter accumulated upon its surface is removed, and when the strainers are composed of coke or coal this matter can be burned as readily as the dried organic matters which have been removed. These methods of removing matters in suspension in sewage are also intended to be quite different in their end results from those obtained by chemical precipitation, sedimentation and septic tanks, in that the organic matter removed by the strainers is left in a compact mass, rather than mixed with many times its volume of water. — Report for 1901, pp. 293, 294.

Strainer E, which is still in operation, has had sewage applied to it at rates varying from 800,000 to 1,800,000 gallons per acre daily at different periods during its eight years of operation, the average rate during the entire period being about one million gallons per acre daily. The amount of coal removed by scraping has been so small that it has been necessary to renew the straining layer but once during the eight years of operation, the average amount of coal removed during this period being about 0.8 cubic yard per million gallons of sewage treated. The removal of organic matter by this strainer has varied somewhat in different years, the average removal being 37 per cent. as shown by the albuminoid ammonia and 38 per cent. as shown by the oxygen consumed results. The average removal of bacteria has been about 56 per cent. The removal of suspended matter has been about 56 per cent. as shown by the albuminoid ammonia in suspension, about 63 per cent. as shown by total solids, and 68 per cent. as shown by loss on ignition.

Strainer F was continued in operation until the end of 1902, a period of about nineteen months, at a rate of one million gallons per acre daily, during which period it was necessary to scrape it but twice. The average removal of organic matter by this strainer was about 20 per

cent. as shown by determinations of albuminoid ammonia, and about 18 per cent. as shown by oxygen consumed. The average removal of bacteria was about 42 per cent. The removal of suspended matter as shown by the albuminoid ammonia in suspension was about 33 per cent., and 42 and 44 per cent. as shown by total solids and loss on ignition, respectively. The average analyses of the effluents of these strainers are shown in the following table: —

Average Analyses of Effluents from Coke and Coal Strainers.

Effluent from Coke Strainer A.

[Parts per 100,000.]

Period.	Ammonia.				Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
	Free.	Albuminoid.					
		Total.	In Solution.	In Suspension.			
June 1, 1894 to Oct. 15, 1898, . . .	3.77	.39	.27	.12	9.86	2.17	1,330,300
Oct. 15, 1898 to Dec. 31, 1900, . . .	3.02	.36	.23	.13	7.54	2.42	676,700

Effluent from Coal Strainer C.

1898-1900, ...	3.53	.35	.23	.12	7.17	2.31	702,600

Effluent from Coal Strainer E.

1901-1903, ...	4.60	.50	.33	.17	11.60	3.09	1,273,000

Effluent from Coal Strainer F.

1901-1903, ...	4.12	.48	.28	.20	10.47	3.06	885,900

Average Solids in Effluents from Coal Strainers E and F.

Effluent from Coal Strainer E.

[Parts per 100,000.]

Period.	Unfiltered.			Filtered.			In Suspension.		
	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.	Total.	Loss on Ignition.	Fixed.
1902-1903, . .	51.9	20.3	31.6	44.9	15.7	29.2	7.1	4.6	2.5

Effluent from Coal Strainer F.

1902, . . .	63.7	26.2	37.5	52.7	18.0	34.7	11.0	8.2	2.8

Septic Tanks.

The first septic tank at the experiment station was started Jan. 1, 1898. On page 445 of the report for 1898 the following statements were made regarding the operation of septic tanks, and it is interesting to note how the predictions then made, when the principles of the septic tank had been studied for only a very short time, have been confirmed by subsequent experiments:—

It is probable that a very much smaller septic tank can be used, in proportion to the volume of sewage flowing, than has been proposed abroad, for this reason; a sewage of ordinary age will, when it reaches its point of disposal, be practically free from dissolved oxygen. If such a sewage is run into a properly built septic tank, no air will be carried with it, and the length of time which it remains in the tank need only be long enough to allow a precipitation of the organic matters in suspension and the accumulation of the fats upon the surface of the sewage. These matters can remain in the tank for an indefinite time, being added to each day by the sewage flowing through, and by the action of the bacteria of decomposition and putrefaction a large percentage of the sludge will be slowly changed to a soluble form, and pass away to a large extent in the effluent of the tank. It seems doubtful if it is necessary to have this tank air tight; it is also doubtful if it is necessary to exclude the light.

During eleven years twelve different septic tanks have been operated at the station, some for periods of a few months only, for the investigation of specific problems, others for many years, in the study of septic tank action in general. Eight of these tanks have received the regular Lawrence sewage as pumped at the experiment station, one has been operated with the sewage of the town of Andover, one with a sewage containing large amounts of mineral salts, such as is found in localities where the water is very hard, one with a sewage containing a much larger amount of organic matter in suspension than is usual in the Lawrence sewage, and one has been used to treat by the septic process the heavy sludge resulting from the operation of a settling tank. While nearly all of these tanks have been of such construction that light and air have been excluded, one tank was constructed of glass, and was open at the top in order that the operation under such conditions might be compared with closed tanks. The proportions of the various tanks have differed widely, although the general plan has been to have the tanks rather shallow, in order that the conditions might favor the deposition of suspended matters and the hydrolysis of the resulting sludge. One of these tanks was filled with broken stone, to study the effect of increasing largely

the opportunity for bacterial action. The period of storage of the sewage in septic tanks has received attention also and has varied from a few hours to many days in different tanks. A septic tank may be considered as having two separate functions, that of clarifying the sewage for subsequent treatment by the removal of a portion of the suspended matters, and that of liquefying or destroying a certain proportion of the organic substances deposited as sludge in the tank, thus reducing the total amount of matter which must ultimately be disposed of in some other manner. In the following chapters the operation of the various experimental septic tanks as bearing on each of these functions will be considered separately. The septic tanks used were, to be sure, of small capacity, but the results in most respects compared well with the results obtained by the use of septic tanks of many thousand gallons capacity in use at various places abroad and in this country.

Septic Tank A. — As stated above, the first septic tank operated at the station was started Jan. 1, 1898. This was a covered wooden tank with a capacity of about 70 gallons. The sewage entered the tank at one end, and was drawn from the other end during the forenoon only of each day, both inlet and outlet being midway between the top and bottom of the tank. For the first two months the tank was operated in this manner, the sewage remaining in the tank about forty-two hours. On March 1, 1898, the contents of this tank were transferred to a new covered tank having about twice the capacity of the old one. This new tank was of wood with a perforated wooden partition dividing it into two equal compartments. The inlet and outlet were located as in the earlier tank. Sewage was passed through continuously at such a rate that it remained in the tank about twenty-four to thirty-six hours. From Jan. 1, 1900, to April 13, 1900, sewage was passed through the tank at such a rate that it remained in the tank about seventeen hours.

On April 13, 1900, the contents of the old tank were transferred to a new tank of somewhat different shape. This was an air-tight wooden tank with a capacity of about 200 gallons, divided by baffles at the top and bottom into three equal compartments. An approximately constant flow of sewage was maintained through this tank at such a rate that it received about sixteen hours' storage. On May 1, 1900, the quantity of sewage passed through the tank daily was changed, so that a storage of about twenty-one hours was obtained. Jan. 1, 1903, the rate of flow was reduced so that the sewage was about nineteen hours in passing through the tank. At the end of March, 1904, about 65 per cent. of the tank capacity was occupied by sludge. As poor clarification results were being obtained, all sludge was removed from the tank and operation was resumed on April 1, 1904, with the sewage flowing so that it remained

in the tank about eleven hours. On Sept. 16, 1904, the rate of flow was again changed, to give a storage period of about thirty-two hours, and the tank was operated in this manner until Nov. 4, 1908, when it was discontinued. The preceding statements concerning time of storage are theoretical, based upon the total capacity of the tank. The actual sewage capacity of the tank and the actual amounts of storage were considerably smaller, because the tanks were occupied to varying depths by deposited sludge. The average analysis of the septic sewage flowing from Tank A is shown on page 474, and the average solids on page 476.

Septic Tank C. — This covered wooden tank with a capacity of about 115 gallons, was started Nov. 28, 1899, in a study of the comparative results observed in purifying regular sewage and septic sewage upon trickling filters. Sewage was passed through the tank continuously at such a rate that the storage period was about twenty-four hours, until the end of September, 1904, when it was discontinued. This tank was not designated by letter in the annual reports of the experiments at Lawrence, the analysis of the effluent being published as "Sewage applied to Filter No. 136." The average analysis of the sewage flowing from Tank C is shown on page 474.

Septic Tank D. — On April 1, 1903, a long, covered tank, divided into five compartments, each with a capacity of about 57 gallons, was put into operation to study the effect of prolonged treatment in a septic tank upon the character of sewage and upon its subsequent purification. The compartments in this tank were separated from one another by baffles at top and bottom, so arranged that a slot 1 inch wide was left for flow of sewage from one compartment to another. Sewage entered at one end of the tank and flowed through the successive compartments to an outlet at the other end, and, at such a rate, that it took about one day to pass through each compartment, and five days to pass through the whole tank. The tank was so arranged that samples of the sewage could be drawn from the outlet end of each compartment, that is to say, when the sewage was one, two, three, four and five days old. At the start a small amount of sludge from Tank A was placed in each compartment to hasten the ripening process. The tank was discontinued on April 15, 1904. The average analyses of the septic sewage from each of the compartments of Tank D are shown on pages 474 and 475.

Septic Tanks G and H. — On May 23, 1904, two covered wooden tanks, each with a capacity of about 115 gallons each, were started to study comparatively the relative removal of organic matter from sewage which remained for different periods in septic tanks. Each of these tanks was divided by baffles into two equal compartments. They were operated until Dec. 31, 1905, the volumes of sewage applied daily being so pro-

portioned that the sewage was about six hours in passing through Tank G and about eighteen hours in passing through Tank H. The average analyses of the septic sewage from these two tanks are shown on page 475, and the average solids on page 476.

Open or Closed Septic Tanks. — In the report for 1898 it was stated to be an open question whether or not it was necessary for a septic tank to be air tight or to exclude the light. From Nov. 7, 1898, to April 7, 1899, two tanks were operated in the study of this point. These were small glass tanks holding about 5 gallons each, one being air tight and protected from the light, and the other open and unprotected. Sewage was passed through these tanks at such a rate that it remained in each about thirty-six hours. So far as could be determined there was no appreciable difference in the action of these two tanks. In the case of the open tank, however, light and air were soon excluded by the formation of a thick scum upon the surface of the sewage, and this is now known to be a common phenomenon in the operation of uncovered septic tanks. The average analyses of the effluents from these two tanks are given on page 475.

"Hydrolytic" Tank No. 133. — From the first, it was evident that the hydrolysis of sludge in a septic tank was caused by the action of anaerobic or putrefactive bacteria, and that the greater part of the work accomplished took place upon the surface of the sludge layer and upon the sides of the tank. On Nov. 10, 1899, Tank No. 133, was put into operation. It was completely filled with broken stone of such size that all would pass through a screen with a 1-inch mesh, 24 per cent. through a ½-inch mesh and none through a screen with a ¼-inch mesh. "The idea in starting this tank," as stated on page 393 of the report for 1900, "was to produce the same action as occurs in an anaerobic or septic tank, but furnishing a much greater surface for bacterial growth than is supplied in a septic tank of the usual construction, and hence with the expectation of obtaining better results." The sewage entered at the bottom and flowed upward through the stones to an overflow at the top. The tank was sealed, to maintain anaerobic conditions, with an outlet for the escape of such gases as should be formed. The open space or sewage capacity at the start was about 45 gallons. During the first four months sewage was passed through at such a rate that it remained in the tank about twenty-two hours. Anaerobic action began soon after the tank was started, as shown by large amounts of gas formed. On March 1, 1900, the rate was increased so that a storage period of about fourteen hours was obtained. On July 13, 1900, the rate of flow was again increased, causing a reduction of the time of storage to about seven hours. Early in May, 1901, it became evident that there was considerable clogging, with obstruction to the free flow of sewage up through the stones,

and on May 16 the rate of flow was reduced so that the sewage remained in the tank about four and one-half days, the purpose being to allow the sludge already deposited to become hydrolyzed, and thus to relieve the clogging. The filter being operated in this manner, an energetic action undoubtedly occurred, as shown by a large increase in the volume of gas formed and in the somewhat more free flow of sewage through the tank. From June 17, 1901, until the end of the year sewage was passed through the tank at a rate which allowed a theoretical storage of about seventeen hours. Capacity measurements made at the end of this period, after the tank had been in operation about twenty-eight months, showed about 68 per cent. of the open space filled with sludge. Experiments were made at this time to determine the feasibility of removing this clogging material by reversing the flow, or by washing the material while in place by the application of large volumes of water or sewage. Such treatment was found to be ineffective, however, with a tank filled with such fine material and without adequate underdrainage. It was stated in the report concerning the operation of this tank, that this method would probably have been successful, however, if the material had been coarser and if the tank had been properly underdrained. The average analysis of the effluent from Tank No. 133 is shown on page 475.

In regard to the hydrolytic tank of Dr. Travis' at Hampton, Eng., concerning which much has been written of late years, it is of interest at this time to make the following quotations from "British Sewage Works," by M. N. Baker: —

Before closing this chapter it will be interesting to make some quotations from a pamphlet by Dr. Travis, to show how he expresses his indebtedness to the Massachusetts State Board of Health for the principles upon which his experimental and practical work at Hampton is based. In the opening paragraph of his pamphlet Dr. Travis states: —

The conception of "The Hydrolytic Tank and Oxidizing Beds" is the result of a close study of the numerous experiments conducted at Lawrence under the ægis of the State Board of Health of Massachusetts, and published by that Board in a series of works which, in their entirety, constitute a classical record of the bacterial purification of sewage.

This being so, an acknowledgment of the source from whence the ideas were derived and a recital of the conclusions having special reference thereto are, as a matter of common honesty as well as of courtesy, equally desirable.

The last paragraph is notable, since not every one who has drawn inspiration from the Lawrence experiments has made proper acknowledgment of the fact, while some have made an acknowledgment in one phrase and belittled the experiments in the next phrase of the same sentence.[1]

[1] About two pages of abstracts by Dr. Travis from the reports of the Mass. State Board of Health for 1899, 1900 and 1901, follow. These are from the discussion of septic tanks, especially Septic Tank B, of hydrolytic Tank No. 133 (described above) and of the clogging of filters by raw and septic sewage.

Andover Septic Tank. — During the year 1898 a system of sewers and a filtration area were constructed at Andover, Mass., and as the conditions seemed to afford an opportunity to study the value of septic tanks upon a somewhat larger scale than had been attempted at the experiment station, a circular, covered, wooden tank, with a capacity of 9,000 gallons, was constructed at the filtration area. A baffle placed 1 foot from the inlet pipe deflected the flow of sewage downward to within 2 feet of the bottom of the tank, and a series of baffles was so placed that the sewage was compelled to travel about 60 feet in passing from the inlet to the outlet.

This tank was started July 10, 1899, and was operated until the end of June, 1902. During 1899 the average storage was about forty-eight hours. From Jan. 1 to May 8, 1900, the storage period was about fourteen hours. From May 9 to July 9, 1900, the sewage remained in the tank about four days. From July 10, 1900, to June 30, 1901, the sewage remained in the tank about fourteen hours, and during the remainder of the year it was about twenty hours in passing the tank. From Jan. 1, 1902, until the tank went out of operation, in June, 1902, the storage period averaged about fourteen hours. The average analysis of the sewage entering and the effluent from this tank are shown on page 475.

Septic Tank E.—Certain published results of the operation of septic tanks in places where the water supply is undoubtedly hard seemed to indicate that with such sewages a chemical precipitation occurred, owing to the passing out of solution in the tank of some of the mineral salts held by the sewage on entrance. In order to determine whether septic tank action would be different with a sewage containing large amounts of mineral salts than with Lawrence sewage, Septic Tank E was put into operation on April 14, 1903. This was a galvanized iron tank with a capacity of about 160 gallons. The tank was divided into two unequal compartments by a baffle 18 inches high, placed 1 foot from the inlet end of the tank. Sewage, to which were added lime and magnesium salts in amounts sufficient to increase the hardness to between 150 and 200 parts per 100,000, was passed through this tank at such a rate that it received about twenty-two hours' storage. The calcium chloride, calcium carbonate and magnesium sulphate used to increase the hardness were added approximately in the proportions in which they were found in a typical hard water. From the beginning of operation there was a voluminous formation of gas in the tank. The effluent had a much darker color than that from other septic tanks in operation at the station, and also a very strong odor of hydrogen sulphide, this odor being due undoubtedly to the decomposition of the large amount of sulphates introduced into the sewage. Some precipitation occurred in the tank and

the effluent was generally somewhat clearer than that from other tanks, although this effect was not so great as had been expected. The results obtained with this tank, however, indicate the reason why septic tanks in some sections of the country produce more offensive odors than do similar tanks elsewhere. This result is due to the different mineral content of the water of those localities, and especially to the presence in such sewages of considerable amounts of sulphates, rather than to the effect of different bacterial reactions or to organic matters of different composition. The sludge accumulating in this tank was unusually offensive. The experiment was discontinued October 15. The average analysis of the sewage entering and the effluent from this tank are shown on page 475.

Treatment of Sludge only in Septic Tank B. — "The observation that the stronger the sewage entering a septic tank the greater the percentage removal of organic matter, suggests the idea that, where exceedingly large volumes of sewage are to be purified, . . . the sewage could be passed through ordinary settling tanks, so constructed that the sludge settling to the bottom of the tanks could be flushed into a septic tank and this sludge alone be treated by septic tank action, instead of attempting to treat the whole volume of sewage." (Report for 1899, p. 422.) Following up this idea, a septic tank was put into operation on Nov. 15, 1899, to receive the sludge obtained by settling regular Lawrence sewage for four hours and by discarding the supernatant 90 per cent. This tank had a capacity of about 20 gallons, and was divided by baffles into two equal compartments. From Nov. 15, 1899, to Feb. 27, 1900, the sludge was passed into the tank in such quantities that it was about 15 days in passing through. On Feb. 28, 1900, the volume of sludge added to the tank daily was increased to such an amount that it was stored in the tank about five days. From April 20, 1900, to Aug. 12, 1901, this tank was operated in such a manner that the strong sewage or sludge remained in the tank a little over two days. On Aug. 13, 1901, a third chamber was added, practically doubling the capacity of the tank, and the storage period was increased to about five days. At the end of the year this third chamber had become completely filled with sludge of such a thick pasty nature that the tank could no longer be operated, and it was discontinued. A discussion of the accumulation and destruction of sludge in this tank is given elsewhere. The average analysis of the sludge entering and the effluent from this tank are shown on page 476.

Treatment of Concentrated Sewage in Septic Tank F.—In Septic Tanks A, C, D, G and H, the effect of varying sizes and shapes, and of different periods of storage, was studied, these tanks being operated with regular Lawrence sewage, and in Septic Tank B, attempts were made, with more or less success, to treat the sludge from a settling tank by the

septic process. On Jan. 27, 1904, Septic Tank F was started to study the effect of septic action upon a sewage containing more organic matter in suspension than was usual in the station sewage, but which was not so dense, and, therefore, more easy to manipulate than the sludge used in the experiments with Tank B. Septic Tank F was a galvanized iron tank with a capacity of about 50 gallons. The sewage applied was obtained by allowing the regular sewage to settle for four hours, after which time the supernatant sewage, equivalent to one-third of the total volume, was drawn off, and the lower two-thirds, containing the suspended matter which had settled from the rejected portion, was run into the tank. The sewage prepared in this manner, containing about twice as much suspended matter as the regular sewage applied to Tank A during the same period, was passed through Tank F at such a rate that it received about five days' storage. The average analysis of the entering sewage, the effluent and solids are shown on page 476.

Average Analyses of Effluents from Various Septic Tanks.

Effluent from Septic Tank A.

[Parts per 100,000.]

Period.	Free Ammonia.	Kjeldahl Nitrogen.			Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Total.	In Solution.	In Suspension.			
Jan. 1, 1898 to Nov. 4, 1903, .	4.57	0.83	0.52	0.31	11.18	3.12	842,300
Effluent from Septic Tank C.							
Nov. 28, 1899 to Sept. 24, 1902,	5.66	0.76	0.56	0.20	9.29	2.48	613,200
Effluent from Compartment No. 1, Tank D.							
April 1, 1903 to April 15, 1904,	4.86	1.14	0.60	0.54	13.73	3.33	1,206,800
Effluent from Compartment No. 2, Tank D.							
April 1, 1903 to April 15, 1904,	4.83	0.86	0.54	0.32	13.63	2.96	881,300
Effluent from Compartment No. 3, Tank D.							
April 1, 1903 to April 15, 1904,	4.91	0.80	0.53	0.27	12.97	2.78	820,400
Effluent from Compartment No. 4, Tank D.							
April 1, 1903 to April 15, 1904,	4.65	0.69	0.44	0.25	12.55	2.69	614,600

Average Analyses of Effluents from Various Septic Tanks — Continued.

Effluent from Compartment No. 5, Tank D.

[Parts per 100,000.]

PERIOD.	Free Ammonia.	Kjeldahl Nitrogen. Total.	Kjeldahl Nitrogen. In Solution.	Kjeldahl Nitrogen. In Suspension.	Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
April 1, 1903 to April 15, 1904,	4.58	0.66	0.44	0.22	11.79	2.57	606,800

Effluent from Septic Tank G.

May 23, 1904 to Dec. 31, 1905,	3.50	0.90	0.52	0.38	10.24	3.44	897,100

Effluent from Septic Tank H.

May 23, 1904 to Dec. 31, 1905,	3.64	0.80	0.50	0.30	10.55	2.98	982,800

Effluent from Open Tank.

Nov. 7, 1898 to April 7, 1899, .	3.92	0.72	0.58	0.14	7.68	2.54	424,000

Effluent from Closed Tank.

Nov. 7, 1898 to April 7, 1899, .	3.88	0.70	0.52	0.18	7.46	2.42	448,000

Effluent from Filter No. 133.

Nov. 10, 1899 to Dec. 31, 1901,	5.03	0.49	0.37	0.12	9.83	2.32	495,500

Average Analyses of Sewage applied to, and Effluents of Various Septic Tanks.

Sewage applied to Andover Septic Tank.

July 1, 1899 to June 30, 1902, .	7.57	2.68	1.55	1.13	11.95	6.91	2,395,500

Effluent from Andover Septic Tank.

July 1, 1899 to June 30, 1902, .	7.07	1.42	1.03	0.39	10.79	4.58	1,583,800

Sewage applied to Septic Tank E.

April 14, 1903 to Oct. 15, 1903,	4.11	1.20	0.47	0.73	37.92	3.81	1,590,900

Effluent from Septic Tank E.

April 14, 1903 to Oct. 15, 1903,	4.02	0.60	0.37	0.23	36.73	3.32	756,800

Average Analyses of Sewage applied to, and Effluents of Various Septic Tanks — Concluded.

Sewage applied to Septic Tank B.

[Parts per 100,000.]

Period.	Free Ammonia.	Kjeldahl Nitrogen.			Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
		Total.	In Solution.	In Suspension.			
Nov. 15, 1899 to Dec. 31, 1901,	4.82	5.77	0.72	5.05	10.09	14.38	7,635,700
Effluent from Septic Tank B.							
Nov. 15, 1899 to Dec. 31, 1901,	6.98	1.46	0.66	0.80	9.83	4.61	765,700
Sewage applied to Septic Tank F.							
Jan. 27, 1904 to Nov. 30, 1907,	5.33	2.31	0.80	1.51	12.40	6.41	1,217,100
Effluent from Septic Tank F.							
Jan. 27, 1904 to Nov. 30, 1907,	6.31	0.72	0.34	0.38	12.51	2.94	497,600

Average Solids in Entering Sewage and Effluents from Septic Tanks.

Tank.	Period.	Entering Sewage.				Tank Effluent.			
		Unfiltered.		Filtered.		Unfiltered.		Filtered.	
		Total.	Loss on Ignition.	Total.	Loss on Ignition.	Total.	Loss on Ignition.	Total.	Loss on Ignition.
A,	1902-1908,	71.5	33.0	50.3	17.4	56.3	21.3	48.3	15.6
B,	1900-1901,	248.6	163.6	60.8	27.0	92.8	44.5	57.8	22.2
C,	1902,	76.9	37.7	53.7	19.9	57.1	22.1	51.0	17.3
F,	1904-1907,	91.2	46.4	53.7	18.7	54.7	17.5	46.2	12.6
G,	1904-1907,	65.9	33.2	47.5	18.2	53.3	23.2	46.0	17.0
H,	1904-1905,	64.6	32.3	47.5	18.6	49.3	20.1	44.8	17.0

Clarification accomplished by Septic Tanks.

The reduction in organic matter in the various tanks, as shown by Kjeldahl nitrogen, varied between 17 per cent. and 75 per cent., Tank D removing the least and Tank B removing the most nitrogenous matter. Six of the tanks showed an average removal of 50 per cent. or more of the organic nitrogen. The removal of organic matter, as shown by oxygen consumed, was slightly less than that indicated by the Kjeldahl nitrogen, the highest being 68 per cent., by Tank B, and the lowest 18 per cent.,

by Tank G. In the case of Tank E an increase is noted in the oxygen consumed, but this was probably due to the somewhat different character of the applied sewage. Six of the tanks removed over 70 per cent. of the suspended matter, as shown by Kjeldahl nitrogen in suspension, the greatest removal being that by the second Tank A, with an average reduction in suspended matters of over 85 per cent., while Tank D-1 was the only one which failed to remove at least 50 per cent. The work of Tank No. 133, the "hydrolytic tank," in which an upward flow of sewage through a bed of broken stone was maintained, was very satisfactory, this tank removing about 83 per cent. of the suspended nitrogen, or more than any of the other tanks receiving regular sewage except the second Tank A. The reduction in bacteria varied between 40 per cent. and 90 per cent., the least satisfactory in this respect being Tank G and the most satisfactory Tank B. Seven of the tanks showed a bacterial removal of over 70 per cent., while only two fell below 50 per cent. These clarification results correspond more or less closely with those obtained with settling tanks. The difference between septic tanks and settling tanks, however, is shown by the effect upon the free ammonia. With two exceptions, all the septic tanks investigated showed an increase in free ammonia, the average increase varying from about 2 per cent. for the third Tank A to about 44 per cent. for Tank B. The first Tank A showed an increase in free ammonia of 81 per cent., but as this tank was in operation about two months only, the period was too short to show definite results. Two of the tanks showed a slight reduction in free ammonia, this amounting to about 2 per cent. in the case of Tank E and about 7 per cent. in the case of the Andover tank. As will be explained later, the reactions taking place in these two tanks were somewhat different from those in the majority of the other tanks at the station.

Since bacteriological action is generally more active in warm weather than in cold, it might be assumed that the efficiency of septic tanks would be affected by differences in temperature, and that different results would be obtained in summer than in winter. The results of the operation of Septic Tank A, extending over a period of more than eight years, afford an opportunity of studying this point. During January, February and March the temperature in this tank, during the eight years from 1901 to 1908, inclusive, averaged 52°F., and during the months of June, July and August of the same years the average temperature in the tank was 72°F. In four of the eight years the reduction in total organic nitrogen was less in summer than in winter, and in one year the reduction was the same in both winter and summer. The average winter reduction was 38.6 per cent. and the average summer reduction was 35.6 per cent.

Similar results are noted in the oxygen consumed, being higher in winter in one period of four years and lower in another similar period. The greatest difference between the winter and summer results was in the reduction of nitrogen in suspension and in bacteria. The average reduction of bacteria in winter was about 72 per cent. and in summer was about 38 per cent., the bacterial removal being greater in summer in only one of the eight years. On the other hand, the removal of suspended matter was greatest in summer in six of the eight years, the average reduction being 46 per cent. in winter and 52 per cent. in summer. The increase in free ammonia corresponded with the higher numbers of bacteria, being greater in summer, when the numbers of bacteria were highest.

In comparing the time of storage of the sewage and the efficiency, the results are complicated by the varying amounts of sludge in the tanks at different times, and the consequent variation in the space through which the sewage must pass and the time required for passage. The results most suitable for comparison are to be found in the operation of Tanks A, G and H, by selecting periods when measurements showed the depth of sludge to be practically constant. Using the periods from May to October only, the actual storage period in Tank A was about seven and one-half hours in 1904, about twelve hours in 1903, 1907 and 1908, about fifteen hours in 1906, and about twenty-two hours in 1905. In this tank the reduction in total organic nitrogen and in oxygen consumed was least when the effective storage was seven and one-half hours and greatest when the effective storage was about fifteen hours. The results with the three twelve-hour storage periods varied considerably among themselves, but all were intermediate between those of the seven and one-half and fifteen-hour storage periods. The removal of suspended matter was also smallest when the sewage passed through the tank most rapidly, but was slightly greater in two of the three twelve-hour periods than during the fifteen-hour period. This tank was less effective in reducing the organic nitrogen, suspended nitrogen and oxygen consumed, when a twenty-two-hour storage was employed than was the case when the sewage passed through more rapidly. In the matter of bacterial removal, however, the efficiency of Tank A increased with the storage. During 1905 Tanks A, G and H were operated under identical conditions, but with different storage periods. The difference in efficiency of these three tanks was very small, Tank G, with a storage period of about four hours, being slightly the most efficient, judging from the nitrogen determinations, with a reduction in organic nitrogen of 41 per cent. and in suspended nitrogen of 59 per cent. Tank H, with an average storage period of about thirteen hours, removed 38 per cent. of the organic nitro-

gen and 58 per cent. of the suspended matter, while Tank A, with an actual storage period of about twenty-two hours was the least effective with a removal of 37 per cent. of the organic nitrogen and 54 per cent. of the nitrogen in suspension. There was no apparent relation between the time of storage and the reduction in oxygen consumed, no relation to the number of bacteria, nor to the increase in free ammonia in these tanks, Tank H showing an oxygen reduction of more than twice that of either of the other tanks, but the lowest bacterial removal and the smallest increase in free ammonia. Tank G showed the highest bacterial efficiency, and Tank A showed the largest increase in free ammonia. From these results it is apparent that the reactions taking place in the different tanks may be different when every effort has been made to operate them in parallel, and for this reason it is impossible to estimate closely the effect of the rate of flow through a septic tank upon its efficiency as a preliminary treatment for sewage. The average efficiency of the various septic tanks during their whole period of operation is shown in the following table: —

Reduction in Organic Matter and Bacteria and Increase in Free Ammonia in Septic Tanks.

Tank.	Period of Operation.	Per Cent. Increase in Free Ammonia.	Per Cent. Reduction.			
			Kjeldahl Nitrogen.		Oxygen Consumed.	Bacteria per Cubic Centimeter.
			Total.	In Suspension.		
A,[1]	Jan. 1, 1898-Feb. 28, 1898,	81.1	35.1	70.8	35.0	89.1
A,[2]	March 1, 1898-April 12, 1900,	4.1	61.8	85.7	52.8	66.7
A,[3]	April 13, 1900-Nov. 4, 1903,	1.7	42.2	55.2	34.3	54.3
B,	Nov. 15, 1899-Dec. 31, 1901,	43.8	74.7	84.1	68.0	90.0
C,	Nov. 28, 1899-Sept. 24, 1902,	28.4	47.2	73.7	41.0	74.4
D-1,	April 1, 1903-April 15, 1904,	13.5	17.2	19.2	24.0	40.4
D-2,	April 1, 1903-April 15, 1904,	12.8	36.2	50.0	32.2	56.6
D-3,	April 1, 1903-April 15, 1904,	14.7	37.9	58.9	36.4	59.7
D-4,	April 1, 1903-April 15, 1904,	8.6	48.3	61.6	38.5	69.7
D-5,	April 1, 1903-April 15, 1904,	7.0	46.5	57.7	41.2	70.1
E,	April 14, 1903-Oct. 15, 1903,	2.2[4]	50.0	68.6	0.0	52.4
F,	1904 to 1907, inclusive,	18.4	68.9	74.8	54.2	74.1
G,	May 23, 1904-Dec. 31, 1905,	5.4	59.5	48.0	18.3	39.8
H,	May 23, 1904-Dec. 31, 1905,	10.6	38.0	57.8	30.5	85.2
133,	Nov. 10, 1899-Dec. 31, 1901,	8.2	65.2	82.9	49.2	78.9
Andover,	July 1, 1899-Dec. 31, 1901,	6.6[4]	47.0	65.5	33.7	53.6

[1] First tank. [2] Second tank. [3] Third tank. [4] Reduction.

Filtration of Septic Sewage.

The effluents from various septic tanks have been applied to intermittent sand, contact and trickling filters, and the results are discussed elsewhere. The peculiar action of some of these filters and the difficulty encountered in purifying septic sewage successfully in some of them have also been commented upon. Since one of the objects in passing sewage through a septic tank is to prepare it for further treatment by filtration, a discussion of the peculiar properties of septic sewage in its relation to filtration may be appropriately inserted at this point. As the sewage flows through a septic tank, more or less of the suspended matters settle out, the preliminary effect being that seen in a settling tank. Later, however, a fermentation of the sludge begins, and gas is formed, some of which is dissolved in the sewage; some of the organic matter is changed from insoluble to soluble forms, which are then taken up by the sewage and carried on to the filters. These dissolved gases and hydrolyzed organic bodies are the ones which constitute the difference between a septic sewage and a settled sewage and as such are important in a discussion of filtration. The filtration of septic sewage, and the cause of the differing results when the effluents from different septic tanks were treated, was fully discussed on pages 387 to 392, inclusive, of the report for 1900. The accumulated data of eight years' further study of septic tanks and of the purification of septic sewage have added little to modify the conclusions drawn at that time. There follow some condensed paragraphs from that report: —

It is noticeable that the septic sewage from Tank A was easily purified by both intermittent sand and by coke contact filters, better purification being obtained when the septic sewage was aerated before application. The sewage from Septic Tank B was purified fairly well by an intermittent sand filter, but only slightly by a coke contact filter that would certainly have produced excellent results if sewage from Septic Tank A had been applied to it. Andover septic sewage was purified to a considerable degree when it was applied to an intermittent sand filter, but we were unable to purify it in either of two coke contact filters to any appreciable extent, or to start nitrification within these filters, except slightly, for a short period. Sewage held in receptacles from seven to fourteen days before being applied to filters was easily purified by intermittent sand filtration, and good nitrification occurred, but we have reason to believe that it could not have been purified in contact filters, although we did not treat this sewage in contact filters. This sewage, however, is not a true septic sewage, but simply a very old or stale sewage. Studying the different results obtained with these different sewages and different filters, a number of facts already known in sewage purification aid in explaining the different results obtained, and special analyses and experiments

that we have made have been of further aid in assisting to a true comprehension of these results. It is, of course, evident that we cannot obtain nitrification within a filter unless there is an ample supply of air held within the pores of the filter in contact with the sewage, to admit of oxidation and nitrification taking place. It is a fact that frequent examinations of the effluents of the sand filters and the coke filter receiving septic sewage A prove that these effluents, when flowing from the filters, contained in almost every instance free dissolved oxygen. The effluent of the sand filter receiving septic sewage B contained generally free oxygen, but the effluent of the coke filter receiving this sewage never contained free oxygen when analyses were made. The effluent from the Andover sand filter rarely contained free oxygen, and the effluents from the Andover coke filters never contained free oxygen at times of examination. In other words, when a small volume of sewage is applied to a sand filter nitrification will take place, no matter to what degree of putrefaction this sewage has attained at the time of its application, if there is an abundance of air to come in contact with the sewage. When, however, sewage in an advanced state of putrefaction is applied to a contact filter, and the entire open space of the filter filled with this sewage, it is possible that oxidation may be so rapid that the supply of oxygen within the filter will be exhausted before the process of nitrification has had time to begin. The slow absorption of oxygen by fresh sewage, and its rapid absorption by very stale or septic sewage, is shown by the following experiments, made in order to throw some light upon the non-nitrification of some septic sewages in contact filters.

The experiments, in which mixtures were made of different sewages with water practically saturated with oxygen and which were examined after standing for varying periods, gave results as follows: —

The per cent. of saturation of the dissolved oxygen of the various mixtures should have been 25 in each case at the time of the first analysis, if no absorption of oxygen had taken place during the manipulation. As a matter of fact, we find that with the regular station sewage 20 per cent. of this oxygen had been absorbed in the three or four minutes ensuing between the time of mixing and the time of analysis. With septic sewage A, 64 per cent. of the oxygen had been absorbed in the same time. With septic sewage B, in one instance the entire amount of free oxygen had been exhausted before the analysis could be made, and in the other instance, 80 per cent. had been exhausted. With the Andover septic sewage, 52 per cent. had been exhausted at the time of the first analysis, and with the sewage thirteen days old 70 per cent. It is further noticeable that the oxygen was not exhausted from septic sewage A until between one and two hours after the experiment was begun. With septic sewage B, however, in one instance the entire amount of oxygen was exhausted immediately, although in another instance more than half an hour elapsed before this entire exhaustion occurred.[1]

[1] Later experiments have shown immediate exhaustion.

As this rapid absorption of oxygen did not cause any change in the character of the organic matter of the sewage that could be detected by the ordinary chemical analyses, experiments were undertaken to show whether or no it was the oxidation or saturation of gases. For this purpose a sample of septic sewage B was first sterilized by heat, this not only killing the bacteria as determined, but expelling all the gases. This sample then had water saturated with oxygen mixed with it, as previously described, and was allowed to stand. At the beginning the per cent. of saturation was 65 and at the end of eight hours 63, showing that sterilizing the sewage by heat had so changed it that this quick absorption of oxygen did not occur. A second sample of septic sewage B was sterilized with mercuric acetate, killing the bacteria but not expelling the gases. This sewage was then mixed with water saturated with dissolved oxygen, and determinations of dissolved oxygen made as before. Immediate examination showed that nearly all the oxygen had been absorbed, instead of 65 per cent. of saturation there being only 3.8 per cent.

These experiments were repeated, and seemed to prove conclusively that the rapid absorption of oxygen was due to gases or to unstable organic matter which would be either expelled by heat or so changed as to be in a more stable condition, and that it could not have been caused by bacterial action.

It is evident from these experiments that if sewage in the condition of septic sewage B flowed into a contact filter, filling it entirely, no nitrification could be expected to take place within the filter, as the oxygen with which it would come in contact would probably not be more than enough for the first rapid oxidation. When such a sewage is run in a comparatively small volume upon the surface of intermittent sand filters, however, it remains upon the surface long enough for considerable oxidation to take place, and it meets a large volume of air as it slowly passes through the filter, and hence nitrification occurs.

These conclusions were confirmed by experiments with contact Filter No. 167 during 1901, in which it was shown that, although the normal effluent from Tank B did not become nitrified in this contact filter, nitrification quickly became active when that effluent was very thoroughly aerated before being applied. A return to the use of non-aerated septic sewage B again caused nitrification to practically cease within a few weeks. (Report for 1901, p. 290.)

While it is clear that oxygen and its rapid exhaustion are important factors in explaining the difficult purification of certain septic sewages, the results obtained in the attempt to purify the Andover septic sewage are not satisfactorily explained. If we assume, however, that the biochemical reactions which occur in different septic tanks containing sludge of varying composition, are different, and give rise to different end-products, the reason for the discordant results obtained in the attempt

to purify the different septic sewages becomes apparent. The very different composition of the gases evolved from Septic Tanks A and B and that from the Andover tank, as shown by the analyses on page 496, and the observations made during the operation of Septic Tank E, would indicate that such an assumption is entirely correct. That such a condition as that occurring in the Andover tank and in Tank B was not entirely due to long storage is shown by the ready nitrification of sewage fourteen days old, and by the results obtained with filters to which the effluents from Septic Tank D and Septic Tank F were applied. As regards the filtration of the septic sewage from Tank D the following statement appeared on page 254 of the report for 1903. "The results showed that with Lawrence sewage the period that the sewage remains in the tank has, with a tank arranged as Septic Tank D, little influence on subsequent purification by sand filters."

Sludge in Septic Tanks.

The essential difference between settling tanks and septic tanks is that the solid matters deposited in the former are removed at frequent intervals and otherwise disposed of, while with the latter the sludge is allowed to remain for longer periods in the tank, where it is subjected to hydrolytic or bacteriolytic action. By these means a portion of the organic matter is converted into unoffensive gases or into soluble compounds which pass off with the outflowing sewage. When septic tanks first came into use it was stated by many that all of the sludge would be destroyed ultimately, and that mechanical handling of sludge would be necessary but rarely. That this view was largely erroneous has been proved by experience, but it is still a fact that a very considerable portion of the deposited matter may be destroyed. Ultimately, however, the space occupied by the deposit increases to such an extent that, if the quantity of sewage for which the tank was designed is passed through daily, the rate of flow becomes so great that the sedimentation of suspended matter is greatly impaired, and under such a condition it is necessary to remove the sludge mechanically. As sludge destruction is dependent on slow bacterial action, and as that action may not become operative immediately it is essential, to get the best results, that septic tanks be cleaned only when absolutely necessary. During the past ten years numerous determinations have been made of the amount of sludge in the various experimental septic tanks, and the results of these measurements, together with analyses of the sludge, have been given in annual reports of the investigations at the station. The results of sludge determinations in Septic Tanks A and B are of special interest, in the former

instance because they extend over a period of many years, and in the latter because of the concentrated character of the sludge treated. The experiments with Tank F were largely a continuation of the studies previously made with Tank B, but with a sludge of somewhat less density, while the operation of Tanks G and H furnish a direct comparison of the effects of different velocities of the sewage flowing through septic tanks upon the accumulation and hydrolysis of the sludge. The results obtained in other septic tanks are largely confirmatory of what had already been learned with these tanks. Since the effect is the same whether the capacity of a septic tank is reduced by sludge at the bottom, or by floating matter at the top, both have been considered together in the following discussion.

Deposition of Sludge. — The most important sludge records in Septic Tank A date from April 16, 1900, when the sludge from a former tank was transferred to a new tank, and operation was begun with the sewage taking theoretically twenty-one hours to pass through the tank. During twenty-nine months, from April 16, 1900, to Sept. 28, 1902, sewage equivalent to 870 times the capacity of the tank was passed through it, and, as a result, the average depth of sludge increased from 2.5 inches to 7.3 inches. The effective capacity of the tank was, furthermore, reduced thereby to less than 60 per cent. of its original capacity, and the actual storage period of the sewage was reduced from eighteen hours to about twelve and one-half hours. On Aug. 11, 1903, after forty months of operation, the accumulated sludge occupied 48 per cent. of the capacity of the tank, and the actual time of passage of the sewage through the tank had decreased to about ten hours. At the end of March, 1904, the accumulated sludge occupied about two-thirds of the capacity of the tank, being 14.5 inches in depth in the inlet compartment, 12 inches in the middle compartment and 8 inches in the outlet compartment. The tank had then been in continuous operation for nearly four years, during which time a volume of sewage equal to more than 1,400 times its entire capacity had been treated. After removing the sludge, operation was resumed with the sewage flowing at such a rate as to give a theoretical storage time of eleven hours. At the end of two months sludge equivalent in amount to 26 per cent. of the volume of the tank had been accumulated. At the end of ten and one-half months no further increase in the sludge was noted, and shortly after this, the theoretical storage time of the sewage in the tank was increased to thirty-two hours. After two years of operation the volume of sludge had increased to about 40 per cent. of the capacity of the tank, and at the end of three years the sludge occupied about 44 per cent. of the tank capacity. In November, 1908, this tank was discontinued after more than four and one-half years of unbroken operation, during which time sewage equiv-

alent to more than 1,500 times the total tank capacity was passed through it. At this time, the depth of sludge was practically the same as at the end of three years, and it was evident that operation could have been continued for some time without removing the sludge. The actual storage time of the sewage in the tank during the last year and one-half of operation was less than twelve hours, instead of the prescribed thirty-two hours, owing to the space occupied by the sludge.

After the Andover septic tank had been in operation about ten months, the sludge amounted to about 10 per cent. of the tank capacity, and no further appreciable increase was noted up to the time the tank was stopped, after about three years of operation. During the last two years there was a hard tenacious scum, from 1 to 3 inches thick, upon the surface of the sewage in this tank.

Septic Tank D was so arranged that the sewage passed successively through five compartments, in each of which it received theoretically twenty-four hours' storage. After seven and one-half months of operation the sludge in the successive compartments occupied 15 per cent., 8 per cent., 4 per cent., 4 per cent. and 8 per cent., respectively, of their capacity. At the end of one year the sludge had become more evenly distributed, and occupied 12 per cent. of the first compartment and 8 per cent. of each of the remaining compartments. The time of operation of this tank was so short that the results show little beyond the fact that the deposit was continuous as the sewage flowed slowly through the tank.

Septic Tanks G and H were operated for one year and seven months, sewage passing through Tank G in about six hours and through Tank H in about eighteen hours theoretically. After three and one-half months of operation the sludge in Tank G was equivalent to 23 per cent., and that in Tank H was equivalent to 13 per cent. of the volume of the tank. After seven and one-half months of operation the sludge in Tank G had increased to about 31 per cent., and in Tank H it had increased to about 25 per cent. of the volume of the tank. During the remaining eleven and one-half months there was no further increase in the amount of sludge in Tank G and only a very slight increase in Tank H. From these results it is seen that the deposit increased at first most rapidly in the tank passing the greater volume of sewage daily, but that, as the tanks were continued in operation, the amount of deposit became practically the same in each.

Septic Tank E was operated with sewage containing an abnormal amount of mineral salts, with the expectation that a precipitation would occur. While such precipitation did undoubtedly take place to some extent, it did not increase appreciably the volume of sludge as compared

with that in other tanks receiving regular sewage. This tank was in operation only about six months, at the end of which period about 22 per cent. of the tank capacity was filled with sludge, the greater proportion being collected near the inlet. This sludge was of an unusually offensive quality, with a strong odor of hydrogen sulphide, undoubtedly caused by the reduction of the added sulphates.

The records of sludge measurements in Septic Tank B are of particular interest, owing to the large amount of suspended matter in the sewage used. The most important sludge records for this tank date from April 18, 1900, when sludge amounting to only about 4 per cent. of the capacity of the tank was transferred to it from an earlier tank. After two months of operation about 33 per cent. of the tank was occupied by sludge and floating matter. At the end of nine months the floating matter had disappeared and the sludge had shrunk to 15 per cent. of the volume of the tank. After about fifteen months, a third chamber was added, which practically doubled the size of the tank, but, notwithstanding this increase in capacity, measurements made a month later showed nearly 40 per cent. of the volume of the tank to be occupied by sludge. After being operated for nineteen months, about 40 per cent. of the volume of the first two compartments was occupied by sludge, and the third compartment had become completely filled with a sludge of such a thick pasty nature that the tank could be operated no longer without cleaning. It is interesting to note that while the tank was standing unused for a period of four months, this sludge shrank to less than one-half its original volume.

In the operation of Septic Tank F were continued the experiments begun with Tank B upon the treatment in septic tanks of sludge alone. and while the sewage entering this tank was much less dense than that treated in Tank B, it contained a much larger proportion of suspended matters than is usually found in sewages entering septic tanks either at Lawrence or elsewhere. During the first five months of operation sludge equivalent to about 19 per cent. of the tank capacity accumulated, but during the remainder of a period of about four years very little further accumulation was noted; in fact, during the last two years of operation there was no measurable increase in the amount of sludge.

The principal sludge measurements, the quantities of sewage treated and the effect of the sludge upon the time of storage of the sewage in Tanks A, B, F, G and H are shown in the following table: —

Volume of Sludge, Amount of Sewage treated and Actual Time Sewage remained in Septic Tanks.

Septic Tank A.

Date.	Months operated.	Sewage[1] passed.	Depth of Sludge (Inches). Inlet.	Depth of Sludge (Inches). Middle.	Depth of Sludge (Inches). Outlet.	Per Cent. of Tank occupied by Sludge.	Time Sewage remained in Tank (Hours). Actual.	Time Sewage remained in Tank (Hours). Theoretical.
April 16, 1900, .	Start.	-	2.5[2]	2.5[2]	2.5[2]	14	18.0	21
Oct. 4, 1900, .	5.5	182	3.5	2.8	2.5	16	17.5	21
Aug. 22, 1901, .	16.0	498	4.0	5.5	4.5	27	15.8	21
Sept. 28, 1902, .	29.0	870	5.0	8.0	9.0	41	12.4	21
Oct. 7, 1902, .	After moving tank.		8.0[3]	8.0[3]	8.0[3]	44	11.8	21
Aug. 11, 1903, .	40.0	1,171	8.0	10.0	8.0	48	9.9	19
March 31, 1904,[4] .	47.5	1,420	14.5	12.0	8.0	64	6.8	19
April 1, 1904, .	Start.	-	-	-	-	-	11.0	11
May 27, 1904, .	2.0	128	7.0	4.0	3.0	26	8.2	11
Sept. 13, 1904, .	5.5	364	4.0	3.0	5.0	22	8.6	11
Jan. 10, 1905, .	10.5	440	5.5	3.8	4.0	24	24.3	32
March 30, 1906, .	24.0	732	8.0	7.0	6.0	39	19.5	32
March 28, 1907, .	36.0	995	10.0	8.0	6.0	44	11.5	32
Nov. 4, 1908, .	55.0	1,506	12.0	6.0	6.0	44	11.5	32

Septic Tank B.

April 20, 1900, .	Start.	-	0.5[2]	-	0.5[2]	4	51.0	53
June 21, 1900, .	2.0	28	7.0	-	1.0	33	35.0	53
Jan. 15, 1901, .	9.0	118	1.5	-	2.0	15	45.0	53
Aug. 22, 1901, .	16.0	223	12.0	4.0	2.0	39	73.0	120
Nov. 18, 1901, .	19.0	241	5.0	5.0	12.0	73	32.0	120

Septic Tank F.

July 6, 1904, .	5.0	32	2.5	2.0	2.3	19	97.0	120
Feb. 18, 1905, .	12.5	69	2.0	2.0	2.0	17	100.0	120
Oct. 4, 1906, .	32.0	181	3.0	3.0	3.0	25	90.0	120
March 28, 1907, .	38.0	216	3.0	3.0	3.0	25	90.0	120
Nov. 30, 1907, .	46.0	264	3.0	3.0	3.0	25	90.0	120

Septic Tank G.

July 12, 1904, .	1.5	143	3	-	-	12	5.3	6
Sept. 14, 1904, .	3.5	320	2	-	4	23	4.6	6
Feb. 16, 1905, .	8.5	643	5	-	3	31	4.1	6
Dec. 31, 1905, .	19.0	1,426	5	-	3	31	4.1	6

Septic Tank H.

July 12, 1904, .	1.5	49	1	-	-	4	17.2	18
Sept. 14, 1904, .	3.5	111	3	-	0.5	13	15.6	18
Feb. 16, 1905, .	8.5	223	4	-	2.5	25	13.5	18
Dec. 31, 1905, .	19.0	273	4	-	3.0	27	13.1	18

[1] In terms of the tank capacity.
[2] Sludge from old tank.
[3] Sludge redistributed after moving.
[4] Tank emptied, sludge removed.

Destruction of Sludge. — The following summary concerning sludge destruction or disappearance is given to show what has been accomplished

with Lawrence sewage in septic tanks rather than to show what may be expected in general, since different sewages yield different results. An experiment made to illustrate how sludge from Lawrence sewage was destroyed by bacterial action was described on page 442 of the report for 1898.

Two glass tubes about 5 feet long and 2 inches in diameter were filled with sludge and allowed to stand until the bacteriolytic action should occur, which would result in the change of the suspended matters into soluble forms according to the septic tank theory, one of these tubes being open and the other sealed. For a few days gases were generated in the sludge and more or less movement of the sludge took place. Shortly, however, this action almost ceased, and samples for analysis showed an almost entire absence of bacterial life. A very few bacteria developed on the culture plates, but forms may have been present which would grow only on plates from which air was entirely excluded. That this was probably true is shown by the fact that after a period of stagnation bacterial life again became active in these tubes, gases were generated and the sludge gradually became disintegrated, helped in the open tube by an abundant growth of pleurococcus. In the septic tank the complete destruction of aerobic bacteria does not occur, on account of the daily change of sewage.

An experiment to ascertain if the destruction of ordinary organic matter contained in sewage would be duplicated with other organic materials is described on page 371 of the report for 1900.

One of the most valuable functions of the septic tanks is the hydrolysis and transformation into gases of cellulose in sewage, such as paper, rags, vegetable matter, etc. As an illustration of this, upon October 4 a considerable quantity of newspaper and cotton and woolen cloth was placed in this tank [Tank A] in wire baskets. Upon December 31 the cloth and paper were still intact, but so rotten that they fell to pieces when touched. The same substances upon the surface of a filter, where oxidation is the principal action, would probably have remained without much change for a much longer period.

Later examinations demonstrated that the cotton cloth and newspaper disappeared entirely in about ten months, but that the woolen cloth remained intact for more than one and one-half years. The results of these experiments have been confirmed elsewhere, and it has been proved that almost any animal or vegetable matter will be destroyed more or less rapidly if placed in a septic tank.

The destruction of organic matter in a number of septic tanks was discussed at some length in the report for 1906, on pages 232 to 235, inclusive, the results showing the amount of suspended matter entering

and leaving the tanks year by year, the amount in each tank and the amount which had been either rendered soluble or passed off as gas. These results have been recomputed to include the data obtained in 1907 and 1908, and the more important results covering the whole period of operation are shown on page 490. These results of analysis and measurement seem to show that more than 80 per cent. of the organic matter deposited in the various septic tanks at the station is passed into solution or is given off as gas. The results show also an apparent decomposition of much mineral matter. This is, of course, due largely to the passage of this matter from the tank undetected, and the discrepancies in the mineral matter results serve as a check upon the organic matter determinations. The time of storage in the various tanks within the limits shown by the table and the strength of the sewage seems to have little effect upon the percentage of organic matter which disappears, or upon the number of pounds of sludge which disappears per million gallons of sewage passing through the tank.

Septic Tank A was cleaned out April 1, 1904, and the operation of this tank is thus divided into two periods of six and one-fourth years and four and one-half years, respectively. During the first period about 70 per cent. of the total suspended matter in the entering sewage was deposited in the tank, but only about 12 per cent. of this suspended matter was found in the tank at the time it was cleaned out, about 82 per cent. of the matter deposited having been destroyed. During the second period about 66 per cent. of the suspended matter in the entering sewage was deposited, but only about one-third of the deposited matter was found to be in the tank at the end of 1908. The results based on the organic matter found in suspension agree somewhat more closely, 70 per cent. and 66 per cent. of the suspended organic matter being deposited, respectively, during the first and second periods, and 88 per cent. and 80 per cent., respectively, of this deposited organic matter disappearing from the tank during the same periods. During the first period the actual time of passage of the sewage through the tank, allowing for the space occupied by the sludge, averaged about twelve hours, varying from eighteen hours at the start to about seven hours at the end, while during the second period the actual time of passage of sewage through the tank averaged about fifteen hours, being about nine hours in 1904, and decreasing from twenty-four hours in 1905 to less than twelve hours in 1908. The amount of suspended matter in the entering sewage during the second period was only about 80 per cent. of that during the first period, and the deposition and destruction of organic matter was also somewhat less, notwithstanding the somewhat longer storage.

In Tank G, in which the sewage remained only about six hours, about 60 per cent. of both total and organic suspended matters were deposited, while in Tank H, with a storage of eighteen hours, the deposition amounted to 75 per cent. of the total suspended matter and 78 per cent. of the suspended organic matter. The destruction of sludge in these two tanks was much the same, 89 per cent. of the total deposited matter and 93 per cent. of the deposited organic matter disappearing from Tank G, and 84 per cent. of the total deposited matter and 90 per cent. of the deposited organic matter disappearing from Tank H.

Notwithstanding the fact that Tank F was operated with sewage containing a much larger amount of suspended matter than were Tanks A, G and H, and that Tank B was operated with sludge from a settling tank, the deposition and destruction of sludge in these tanks agree very closely with the results obtained with the other tanks. The amount of suspended matter in the sewage applied to Tank F was about one and one-half times as much as that in the sewage applied to Tank A, and a little more than twice that in the sewage entering Tanks G and H. In this tank, 76 per cent. of the total suspended matter and 82 per cent. of the suspended organic matter in the applied sewage were deposited, and 71 per cent. of the total deposited matter and 86 per cent. of the deposited organic matter were destroyed. The sewage entering Tank B contained about ten times as much suspended matter as that applied to Tanks G and H. In this tank 82 per cent. of the total suspended matter and 84 per cent. of the suspended organic matter were deposited, and 74 per cent. of the total deposited matter and 82 per cent. of the deposited organic matter were destroyed.

The amount of total and organic suspended matter entering and leaving the various tanks, and the amounts destroyed, are shown in the following table: —

Deposition and Destruction of Sludge in Septic Tanks A, B, F, G and H.

	Tank A.		Tank B.	Tank F.	Tank G.	Tank H.
	Jan. 1, '98. Apr. 1, '04.	Apr. 1, '04. Nov. 4, '08.	Nov. 15, '99. Nov. 18, '01.	Jan. 27, '04. Nov. 30, '07.	May 23, '04. Dec. 31, '05.	May 23, '04. Dec. 31, '05.
Gallons applied,	329,600	275,385	5,994	13,150	162,600	56,600
Pounds Total Suspended Matter per Million Gallons.						
Entering tank,	2,290	1,810	14,300	3,040	1,470	1,390
Leaving tank,	675	617	2,540	720	585	356
Deposited,	1,615	1,193	11,760	2,320	885	1,034
Found in tank,	286	414	3,020	676	100	168
Disappearing,	1,329	779	8,740	1,644	785	866

Deposition and Destruction of Sludge in Septic Tanks A, B, F, G and H — Concluded.

Per Cent. of Total Applied Suspended Matter.

	Tank A.		Tank B.	Tank F.	Tank G.	Tank H.
	Jan. 1, '98. Apr. 1, '04.	Apr. 1, '04. Nov. 4, '08.	Nov. 15, '99. Nov. 18, '01.	Jan. 27, '04. Nov. 30, '07.	May 23, '04. Dec. 31, '05.	May 23, '04. Dec. 31, '05.
Leaving tank, ...	29.4	34.1	17.7	23.7	39.8	25.5
Deposited, ...	70.6	65.9	82.3	76.3	60.2	74.5
Found in tank, . . .	12.0	22.9	21.1	22.2	6.8	12.1
Disappearing, . . .	58.6	43.0	61.2	54.1	53.4	62.4
Per Cent. of Total Suspended Matter deposited.						
Found in tank, . . .	17.7	34.7	25.7	29.2	11.3	16.3
Disappearing, . . .	82.3	65.3	74.3	70.8	88.7	83.7
Pounds Suspended Organic Matter per Million Gallons.						
Entering tank, . . .	1,670	1,300	10,400	2,360	1,190	1,130
Leaving tank, . . .	500	443	1,630	425	478	246
Deposited, ...	1,170	857	8,770	1,935	712	884
Found in tank, . . .	139	176	1,580	266	48	85
Disappearing, . . .	1,031	681	7,190	1,669	664	799
Per Cent. of Applied Suspended Organic Matter.						
Leaving tank, . . .	29.9	34.1	15.7	18.0	40.2	21.8
Deposited, ...	70.1	65.9	84.3	82.0	59.8	78.2
Found in tank, . . .	8.3	13.5	15.2	11.3	4.0	7.5
Disappearing, . . .	61.8	52.4	69.1	70.7	55.8	70.7
Per Cent. of Suspended Organic Matter deposited.						
Found in tank, . . .	11.9	20.5	17.9	13.8	6.9	9.6
Disappearing, . . .	88.1	79.5	82.1	86.2	93.1	90.4

Composition of Septic Tank Sludge.—A number of analyses were made of the sludge from the various tanks at the station, from which analyses some idea may be obtained as to the composition of the sludge in different tanks, in different parts of the same tank and in the same tank at different times, although the number of determinations on any one tank were so few that only general conclusions can be drawn.[1] The greatest proportion of organic matter was found in the sludge from Tank F, that from Tank B containing considerably less, although it received a much stronger sewage. The sludge from Tank E contained the smallest proportion of organic matter, the large amount of mineral matter being due

[1] Analyses of sludge from each of the three compartments of Tank B are given on page 285 of the report for 1901, and analyses of the sludge from the inlet and outlet compartments of Tanks A, G and H are given on page 238 of the report for 1906.

to the salts added to increase the hardness of the entering sewage. The proportions of fat, carbon and hydrogen varied but little in those sludges upon which they were determined. The analyses of sludge in various parts of the tanks vary more or less and the results are not entirely consistent. In Tanks A and G a greater proportion of organic matter was found in the sludge near the inlet on one occasion and in that from near the outlet on another occasion. In Tanks B and F the organic matter was greatest in amount in sludge from the vicinity of the inlet in the single analysis made, while in Tank H a similar result was obtained in both of the determinations. In Septic Tank A, the proportion of mineral matter appears to have increased and the per cent. of organic matter to have decreased correspondingly as the tank was continued in operation. In Tanks F and H, also, the proportion of organic matter in the sludge decreased during the last year of operation, but the reverse appears to be true for Tank G. From February, 1905, to March, 1906, the proportion of organic nitrogen and of fats in the sludge in Tank A increased, but at the end of operations in November, 1908, both organic nitrogen and fats had decreased to about the proportion found in 1905. In both Tanks G and H a slight decrease is noted in the per cent. of fats and organic matter in the sludge. A representative analysis of the sludge from each of these septic tanks is contained in the following table: —

Percentage Composition of Dry Septic Tank Sludge.

Tank.	Date of Examination.	Mineral Matter.	Total Organic Matter.	Organic Nitrogen.	Fats.	Carbon.	Hydrogen.
A,	Mar., 1906, . .	54.6	45.4	2.7	11.9	25.1	3.0
B,	Dec., 1901, . .	45.6	54.4	2.6	-	-	-
E,	Oct., 1903, . .	70.9	29.1	1.1	8.8	-	-
F,	Nov., 1907, . .	60.1	39.9	2.1	-	-	-
G,	Dec., 1906, . .	50.7	49.3	2.9	11.8	29.8	4.0
H,	Dec., 1906, . .	51.0	49.0	2.8	10.8	27.7	3.8

Gas from Septic Tanks.

As soon as septic tanks began to be operated and their action studied, it was noticed that considerable amounts of inflammable gas were formed, and statements appeared occasionally concerning the volume of such gas and its utility as an illuminant. In 1898, experiments were made to determine whether gas was formed from the soluble matters in sewage, or only from the sludge, bottles containing sewage with and without sludge being fitted with manometer tubes and allowed to stand in the dark for a long period. Profuse gas formation in the bottles containing sludge, and the absence of such action in those from which it was absent. demonstrated that the source of the gas was the suspended rather than

the soluble matters. During five months in 1898 and 1899 (report for 1899, p. 423) the gas formed in a small glass septic tank was measured and was found to amount to about 1 gallon for every 22½ gallons of sewage passed through the tank, or about 5,900 cubic feet of gas per 1,000,000 gallons of sewage. The storage period in this tank was about thirty hours.

A number of series of measurements made of the gas production in Septic Tank A in 1900 were reported on page 373 of the report for that year. From April 21 to May 1, with a temperature of 51°F. and an average storage of twenty-eight hours, gas was produced at a rate of 6,100 cubic feet per 1,000,000 gallons of sewage passed by the tank. From May 2 to May 22, with a storage period of twenty-one hours and an average temperature of 52°F., the rate of gas production was 8,400 cubic feet per 1,000,000 gallons. In July, with the sewage about twenty-eight hours passing the tank and a temperature of 74°F., the volume of gas increased to over 11,000 cubic feet per 1,000,000 gallons of sewage, but in October, when the temperature had dropped to 65°F. and the storage period had been reduced to twenty-three hours, the gas production was only about 6,000 cubic feet per 1,000,000 gallons. During the July measurements about 62 per cent. of the sewage passed through the tank between the hours of 8 A.M. and 4 P.M., and only about 41 per cent. of the gas was formed during the same period. In October 57 per cent. of the sewage passed the tank during the day and only 18 per cent. of the gas was formed in the same time. These results disagree and show little relation between the temperature or the time of passage of sewage through the tank and the amount of gas formed, nor does a careful study of the individual measurements indicate any such relation. A further study of the results fails to indicate any relation between the volume of sewage contained in the tank and the amount of gas formed or between the volume of sludge and the amount of gas. The results of these measurements and the ratio of gas formation to the volumes of sewage and of sludge are shown in the following table: —

Gas Production in Septic Tank A.

	April 21 to May 1.	May 2 to May 22.	July 10 to July 20.	October 4 to October 6.
Average storage in tank (hours),	28	21	28	23
Average temperature in tank (degrees),	51	52	74	65
Cubic feet of gas formed per 1,000,000 gallons of sewage passed.	6,100	8,400	11,300	6,000
Cubic feet of gas formed per 1,000 gallon tank capacity.	5.3	9.5	9.5	5.3
Cubic feet of gas formed per cubic foot of sludge in tank.	0.71	1.27	1.27	0.71

In 1907 and 1908 experiments were made to determine whether any relation exists between the amount of organic matter in sludges and the gas production. To this end one sample of sludge from Septic Tank F, one sample of sludge from a tannery sewage, two samples of sludge from a settling tank receiving regular Lawrence sewage and two samples of sludge resulting from the sedimentation of the effluents from trickling filters, were placed in 2-gallon bottles, which were then completely filled with the liquid from which the sludge was obtained, and allowed to stand in the laboratory. Any gas formed was collected over the liquid from which the sludge was obtained, and the experiments were continued as long as gas was formed. The sludge from tannery sewage failed to produce any gas during two months; one sample of regular sewage sludge, containing 292 grams of solids, of which 84 per cent. was organic matter, produced only about 100 cubic centimeters of gas in twenty-six days, another sample, of 258 grams, of which 78 per cent. was organic matter, gave 1,500 cubic centimeters of gas in three weeks; 314 grams of sludge from Septic Tank F, after it had been out of operation two months, containing 46 per cent. organic matter, produced 1,300 cubic centimeters of gas in a month; 339 grams of sediment from the effluents of trickling Filters Nos. 135 and 136, containing 44 per cent. organic matter, produced 950 cubic centimeters of gas in one month; 1,028 grams of sediment from the effluent of trickling Filter No. 248, containing 45 per cent. organic matter, produced 56 liters of gas in two months. Thirty-two per cent. of the nitrogen and 15 per cent. of the carbon contained in this sample were given off as gas.

It is evident from these results that the production of gas varies with the character of the sludge and with its susceptibility to fermentation, and is not wholly dependent upon the amount of organic matter present. The nonfermentation of the sludge from the tannery sewage may have been due to the fact that this sewage contained small amounts of arsenic. Active fermentation, however, frequently occurs in the settling tanks at the tannery from which the sewage was obtained, and the failure of gas production in this sample cannot be explained entirely on the ground of antiseptic action. The two samples of sludge from Lawrence sewage were similar, as far as could be determined, and were kept in the laboratory under identical conditions, yet one sample produced more than eighteen times as much gas per gram of organic matter as the other. The sludge taken from Septic Tank F had already been subjected to putrefactive action for a considerable time, nevertheless the gas production from this sludge was greater than that from the fresh sludge. A similar difference is noted in the case of the sediments from the trickling filter effluents. The filters from which these were obtained were all giv-

ing highly nitrified and nonputrescible effluents, and presumably the sludge was in much the same condition. One sample, however, produced nearly twenty times as much gas as the other. The amounts of gas produced from the various samples are shown in the following table: —

Amount of Gas produced by Fermentation of Sludge from Sewages and Effluents from Trickling Filters.

Sludge from —	Days.	Per Cent. Organic Matter in Sludge.	Cubic Centimeters of Gas formed per Gram of —	
			Sludge.	Organic Matter.
Tannery sewage,	61	51	0.00	0.00
Lawrence sewage,	26	84	0.34	0.40
Lawrence sewage,	21	78	5.80	7.45
Septic Tank F,	30	46	4.14	9.00
Effluents of trickling Filters Nos. 135 and 136,	30	44	2.80	6.37
Effluent of trickling Filter No. 248,	60	45	54.40	121.00

The principal ingredients of septic tank gases are methane, carbon dioxide and nitrogen, but the proportions vary considerably in the gases obtained from the different tanks. An analysis of the gas from Tank A was given on page 422 of the report for 1899, and analyses of the gas from Tank B and the Andover tank were given on page 392 of the report for 1900. These analyses show a variation in the amount of carbon dioxide in the septic tank gases from 3.4 per cent. in gas from Tank A to 42.2 per cent. in gas from Tank B; in the amount of methane, from 28.7 per cent. in the Andover septic tank to 79.0 per cent. in Tank A; and in the amount of nitrogen, from 16 per cent. in Tank A to 61 per cent. in the gas from the Andover tank. In the gas from Tank A, small amounts of carbon monoxide, oxygen and "heavy hydrocarbons" were reported, but no tests for these were made on the other samples. No hydrogen was found in any of the samples, although this is a common ingredient in the gases from the fermentation of carbohydrates. The gas from Tank B and the Andover tank was obtained by warming the sewage and collecting the dissolved gases, as no provision was made for collecting the gas from these tanks, but the method of collecting the gas probably had little influence upon its composition.

The composition of the gases obtained in the experiments on the fermentation of sludges previously mentioned also showed a wide variation. The carbon dioxide varied between 11.7 per cent. in the case of the gas from Septic Tank F sludge to 28.7 per cent. in the case of the gas from

regular sewage sludge, and the nitrogen varied between 12.4 per cent. for the gas from Septic Tank F sludge and 69.5 per cent. for the gas from regular sewage sludge. The greatest variation was in the proportion of methane, the Tank F sludge yielding a gas containing about 76 per cent., while the gas from regular sewage sludge contained only about 2 per cent. The gas from the two samples of sewage sludge were practically identical, and there was not a great difference in the composition of the gas from the trickling filter sediments. It was noticeable that as the fermentation of the sediment from Filter No. 248 effluent neared the end, the odor of hydrogen sulphide became more and more marked, although that gas was not present in measurable amounts nor has hydrogen sulphide ever been detected in measurable amounts in the gases from any of the septic tanks. The analyses of the various gases are shown in the following table: —

Analyses of Gas from Septic Tanks and Fermentation of Sludges.

Gas from—	Per Cent.		
	CO_2.	CH_4.	N.
Septic Tank A,	3.4	79.0	16.0
Septic Tank B,	42.2	37.5	19.0
Andover septic tank,	9.8	28.7	61.0
Sludge from regular sewage,	28.7	1.8	69.5
Sludge from Septic Tank F,	11.7	75.9	12.4
Sediment from Filters Nos. 135 and 136,	16.2	66.3	17.5
Sediment from Filter No. 248,	20.5	66.6	12.9

Disposal of Sewage Sludge by Destructive Distillation.

As stated previously, the disposal of the sludge resulting from the removal of suspended matters from sewage by chemical precipitation and by settling tanks is a serious problem in the operation of large sewage disposal works. In septic tanks a considerable proportion of the sludge may be destroyed, but there is always a certain amount of sludge which must be removed and otherwise disposed of. In addition, a large amount of suspended matter is carried in the effluents from trickling and contact filters which in many instances must be removed by settling tanks, and the resulting sludge disposed of. Experience has shown that while these various sludges have some value as fertilizers. the proportion which is utilized in this way is small. During the past two or three years the disposal of sludge by destructive distillation with the utilization of the gases formed has been proposed, and some experiments of this kind are under way in England and Germany, but no results have been published.

During 1908 studies of the destructive distillation of sludges from different sources were begun at the experiment station. In these investi-

gations about 400 grams of dried sludge were placed in a cast-iron retort, which was slowly heated to a bright-red heat. The gases evolved were passed through a wash-bottle containing sulphuric acid to absorb the ammonia, and were then collected over water in a receiver in which the volume of gas produced was measured and from which average samples of the gas were taken for analysis. The distillation process was carried out on two or more samples of the sludge from each source. The experiments up to the present time include tests of the sludge from settling tanks in four different cities and towns, from one chemical precipitation works, from one septic tank, from one settling tank receiving the effluents from trickling filters and the sludge resulting from the evaporation of the waste liquors from the manufacture of sulphite pulp. For purposes of comparison, tests have been made also of the gases evolved in the destructive distillation of peat, sawdust, wood pulp and soap grease, and of four grades of bituminous coal, one of which was that used by a large gas company for the production of illuminating gas. The volume of gas produced from different samples of the same kind of sludge and from sludges of different kinds has varied considerably. The amount of gas produced per ton of dry sludge averaged about 6,600 cubic feet for settled sewage sludge, 8,100 cubic feet for chemically precipitated sewage sludge, 4,900 cubic feet for septic tank sludge, and 6,000 cubic feet for sediment from the effluents from trickling filters. The residue from the evaporation of sulphite pulp liquor produced about 11,000 cubic feet of gas per ton. In comparison about 12,000 cubic feet of gas were obtained from both sawdust and wood pulp, about 8,400 cubic feet from peat and about 5,300 cubic feet from soap grease, while the different kinds of soft coal yielded from 8,600 to 12,900 cubic feet of gas per ton. The composition of the gases from different sources was quite different. In general, the gases from sludge contained a much larger proportion of CO_2, of CO and of the so-called illuminants than the gas produced from coal, while the proportions of hydrogen and methane were correspondingly less. Gases of similar composition are used successfully in many places, however, as sources of light and heat. The coke resulting from the distillation of the various sludges amounted to 45 to 65 per cent. of the weight of the dry sludge, and, in spite of the fact that it was usually very soft and friable and that it contained a large proportion of mineral matter, this could undoubtedly be burned on properly constructed grates, and the heat used either for making steam or for drying the wet sludge. Analyses of the coke also showed it to contain from 1.1 to 1.7 per cent. of available P_2O_5 and on an average about 22 per cent. of the nitrogen of the sludge, and it is possible that it might profitably be used as a basis for the

manufacture of fertilizer. The per cent. of P_2O_5 might be increased by burning the sludge more completely, but this would cause the removal of the nitrogen, which is a desirable ingredient if the coke is to be used for this purpose. Much of the fats in the sludge distilled over with the tars, resulting in a light, greasy tar. This by-product of the process could readily be disposed of by mixing it with the coke and burning, or if it were formed in sufficient amounts it could be burned directly, in the same manner as water gas tars are utilized. The average results of the investigation are shown in the following tables:—

Analyses of Sludges used for Destructive Distillation, Per Cent. of Coke formed and Amount of Nitrogen in Coke.

	Composition of Sample before Distillation (Per Cent.).			Per Cent. of Coke produced.	Per Cent. of Nitrogen.[1]		Per Cent. Available P_2O_5 in Coke.
	Total Nitrogen.	Loss on Ignition.	Fats.		Found in Coke.	As NH_3 in Washer.	
Lawrence sludge,[2]	3.36	36.8	12.8	63.5	.11	.586	1.33
Andover sludge,[2]	2.14	46.6	27.5	59.5	.67	.226	1.38
Clinton sludge,[2]	2.36	74.4	7.7	44.5	.73	.404	1.44
Brockton sludge,[2]	1.76	46.0	6.2	60.5	.94	.137	1.17
Worcester sludge,[3]	1.19	44.5	3.2	54.0	.09	.544	1.67
Septic tank sludge,	2.46	47.9	8.3	68.5	.27	.497	1.15
Trickling filter sludge,	2.10	48.3	4.9	62.0	.56	.809	1.31
Sludge from evaporation of sulphite pulp liquor.	-	87.3	-	32.0	-	-	-
Peat,	2.54	92.0	-	49.0	.70	.700	0.31
Sawdust,	0.00	-	-	25.0	-	.000	-
Wood pulp,	0.00	-	-	25.0	-	.000	-
Soft coal,[4]	-	96.8	-	77.3	-	.232	-

[1] Per cent. by weight of total sludge taken.
[2] Settled sewage sludge.
[3] Chemically precipitated sludge.
[4] Average of four kinds of steam and gas coal.

Relative Volume and Composition of Gases produced by Destructive Distillation of Sewage Sludge.

	Cubic Feet of Gas per Ton of Sample.	Per Cent.						
		CO_2.	Illuminants.	O.	CO.	H.	CH_4.	N.
Lawrence sludge,[1]	4,900	4.4	2.2	0.3	30.7	34.9	18.6	9.1
Andover sludge,[1]	6,400	7.4	15.1	0.6	14.3	22.9	34.3	5.4
Clinton sludge,[1]	9,100	8.3	6.7	0.0	20.4	33.2	24.5	7.0
Brockton sludge,[1]	6,000	16.5	21.4	0.2	10.3	22.6	29.1	0.2
Worcester sludge,[2]	8,100	14.2	4.9	0.3	29.8	32.6	16.2	2.2
Septic tank sludge,	4,900	7.5	1.0	0.1	24.3	44.0	13.0	10.2
Trickling filter sludge,	6,000	20.2	17.4	0.3	6.6	32.7	22.8	0.0
Sludge from evaporation of sulphite pulp liquor.	11,000	21.6	2.1	0.0	20.0	42.0	12.0	0.3
Peat,	8,400	39.0	4.7	0.2	11.0	28.0	17.1	0.0
Sawdust,	12,700	18.4	4.8	0.3	28.2	26.9	19.1	2.3
Wood pulp,	12,000	23.5	1.4	0.0	16.4	44.5	13.3	0.9
Soap grease,	5,400	6.8	44.5	0.0	6.2	15.8	26.7	0.0
Soft coal,[3]	10,200	1.6	2.0	0.1	5.2	62.3	25.7	3.2
Lawrence illuminating gas,[4]	-	3.4	9.1	0.0	21.5	42.5	19.7	3.8

[1] Settled sewage sludge.
[2] Chemically precipitated sludge.
[3] Average of four kinds of steam and gas coal.
[4] From gas company pipes at experiment station.

Bacteriology of Sewage and Sewage Purification.

Since the beginning of the experiments at Lawrence much attention has been given to the study of the bacteria in sewage and in the effluents of various types of sewage filters. As stated in the special report for 1890, p. 798, "The aim of the biological work has been to discover the origin, functions and fate of the various organisms concerned in sewage disposal; to differentiate the functions of the organisms involved, so as to learn the conditions of their usefulness, or, if necessary, of their removal."

The data concerning the numbers of bacteria in samples from the various sources have been published annually. Much information has also been acquired as to kinds of bacteria, as to the removal of bacteria of certain types; as to the biochemical reactions occurring in filters, and the types of bacteria causing the reactions. In addition, investigations have been continuously in progress leading to improvements in the methods by which the numbers and kinds of bacteria in water and sewage are determined, and to make clear the significance of the results of bacteriological analyses.[1]

The results of many of these investigations have been published as special papers, either in the annual reports or in various scientific journals. While many of these studies have related especially to the analysis of water, the knowledge of bacteriological methods thus obtained is equally applicable to the analysis of sewage and the effluents of sewage filters. During the first few years microscopical analyses were made, and much was learned about the fauna and flora of sewage and the effluents of intermittent filters, and about the fate of the microorganisms other than bacteria. These data are closely related to the bacteriological investigations and for this reason have been included with them. In the following pages it has been attempted to present results and conclusions in chronological order, and, as far as brevity will permit, in quotations from the original reports.

[1] A description of the methods of bacteriological analysis first employed is given on p. 811 *et seq.* of the special report for 1890. The improved bacterial methods and technique were described in a special paper, on p. 585 *et seq.* of the 1895 report. The methods for the isolation and differentiation of B. coli were discussed in the 1898 report, p. 583 *et seq.*, and certain modifications and improvements in the B. coli methods were given in a special paper on p. 398 *et seq.* of the 1901 report. In 1904, methods for the determination of the quantitative biochemical functions of the bacteria in sewage, and the effluents from sewage filters, were devised, and were described on p. 241 of the report for that year. In 1906, determinations of bacteria at 20° C. and 40° C. were made a part of the routine analyses of all samples, and the significance of the numbers of bacteria determined at different temperatures was discussed in a special paper on p. 325 *et seq.* of the 1906 report. Since 1905, the standard methods for the analysis of water and sewage adopted by the American Public Health Association, which agreed quite closely with the methods in use at Lawrence, have been followed, except in a few minor particulars.

Early Work, 1888–1893.

When the experiments upon the purification of sewage were started at Lawrence, bacteriology and bacteriological methods were in their infancy. Only six years before, Koch had proposed the use of solid media, by the use of which quantitative determinations of the numbers of bacteria and the isolation and study of species of bacteria became possible. The use of the Petri dish, which extended the scope of the Koch methods and made possible the rapid and accurate bacterial examinations now so common was proposed in the same year that the Lawrence experiments were inaugurated, but was not generally adopted till some years later. The bacteriology of sewage and its purification was an unexplored field. Almost from the beginning of the experiments, determinations of the numbers of bacteria in the sewage, in the effluents from the various filters and in the filtering materials were made a part of the investigations, and the results of those analyses, and of the special investigations which they suggested, did much to explain the cause and effect of sewage purification by intermittent filtration, and to forecast the results which would be obtained by other methods of treatment. Except in a very few particulars, the interpretations which were placed upon those early results have remained unchanged by further investigation.

Relation of Numbers of Bacteria in the Effluent of a Filter to its Rate of Flow.

With sand filters it was noticed early that after the first portions of sewage appeared at the outlet, the rate of flow increased rapidly to a maximum, and then gradually decreased until the filter was drained or until another application of sewage was made. To determine the relation between this and the fluctuating numbers of bacteria found in the effluents from some of the filters, series of samples were collected, beginning before the application of sewage and continuing at intervals for some hours.

The results of these experiments proved that there is a time, not long after the application of the sewage, when the number of bacteria discharged per unit of volume is many times greater than at any other time. Moreover, as this period coincides in a general way with the period of rapid flow, it follows that the majority of bacteria discharged during the day escape during a comparatively limited time. A sample taken at this time differs widely from one taken before flowage, or long after. In this way irregularities were easily accounted for and a regular and important variation in the bacterial discharge was discovered. — Special report for 1890, p. 849.

These facts determined the period when samples should be collected for analysis, and since that time samples have been collected at the period of maximum flowage, such samples representing the greater proportion of the total volume of the effluent more fairly than would samples taken at any other time.

Effect of Intermittent Filtration upon Bacteria.

When sewage was first applied to the sand filters, the number of bacteria found in the effluents, while the sewage was mingling with water that was previously in the sand, rose from the small numbers that had been in the water to appreciable percentages of the number that was in the sewage, and, in the case of Tank No. 11, exceeded that number. The maximum percentages of the number in the sewage found in the effluents at such times were as follows: No. 1, 31 per cent.; No. 12, 83 per cent.; No. 13, 40 per cent.; No. 14, 26 per cent.; No. 6, 5 per cent.; No. 11, 487 per cent.; No. 2, 14 per cent.; No. 4, 5 per cent.; No. 7, 5 per cent. These results show us that it is mechanically possible for bacteria to be carried through the several filters of sand in large numbers, and with varying percentages of loss; and that when the number brought through is far below the percentages above given, we must conclude that some other condition, not merely mechanical, is unfavorable to their passage. Immediately after the water that had been in the sand of the several filters had been pushed out by the incoming sewage, the number of bacteria decreased.

The conditions under which these great changes occurred, which are common to all of the filters, were these: when the sewage was first applied, with its half million of bacteria in each cubic centimeter, it mingled with water in the sand which contained some absorbed oxygen and some oxygen brought down mechanically from the surface; and with this supply of oxygen and there being no known burning up of organic matter, from 5 to 40 per cent. of the bacteria appear to have been able to survive the passage of from two to five days through the coarse sand, and from ten to twenty days through the finer sands. But when sewage took possession of the tank there was no absorbed oxygen in the liquid, and the amount of oxygen taken in mechanically was used up to a considerable extent in combining with the organic matter; and it appears that there was not enough left to support more than a small fraction of 1 per cent. of the bacteria on the passage through the sand. During this period of partial purification without nitrification we have in the effluents an average of about 1 per cent. of the number of bacteria in the sewage. — Special report for 1890, pp. 587, 588.

After this nitrification began, and as the nitrates increased the average numbers of bacteria in the effluents gradually decreased.

While this change to an established condition of purification of the effluent was going on, the numbers of bacteria in the effluents were on an average 0.06 per cent. of the number in the sewage. We now reach the con-

dition in which the several effluents were in well-established purification through nitrification. Selecting the first month of each, when the nitrates averaged 1.03 parts, the percentages of the number of bacteria of the sewage found in the several effluents averaged 0.07. Finally, after the filters had been filtering sewage for a year or more, the average condition of the effluents was 0.05 per cent. of the numbers in the sewage. — Special report for 1890, p. 590.

Bacteria decrease with Completeness of Nitrification, independently of the Ammonias.

We have seen that it is mechanically possible for from 5 to 40 per cent. of the number of bacteria applied in the sewage to pass through the several filters; but that, after intermittent filtration is established and no nitrification is taking place, 99 per cent. of the bacteria are destroyed; and, when nitrification begins, the number surviving the passage suddenly decreases to only 0.08 of 1 per cent., and still further decreases to about 0.03 of 1 per cent. when nitrification becomes complete. During each of these stages there appears to be no lack of food for bacteria. In the stages which follow, a decrease in the sum of the ammonias is not accompanied by a further decrease in the number of bacteria. We do not here find that the number of bacteria, after nitrification begins, decreases with the decrease in the sum of the ammonias; but it does decrease with the completeness of the nitrification.

As free ammonia is generally an indication of organic matter that previously existed, it may be that in these effluents it is not, even when abundant, in a form that serves as food to bacteria; and, as the changes noted are in great part changes in free ammonia, it will be useful to examine the amounts of albuminoid ammonia in the effluents at the several periods. Here we find the albuminoid ammonias, at the several periods, nearly constant at 2 or 3 per cent. of the albuminoid ammonia of the sewage, but there appears to be no relation between the number of bacteria and the amount of albuminoid ammonia. For example, we find the same amount of albuminoid ammonia when the number of bacteria in the effluents averaged 18 per cent. of the number in the sewage as when the number was only 0.077 of 1 per cent.; hence we cannot ascribe the difference in number in the latter case to be due to the want of albuminoid ammonia for food. It is possible, however, that the albuminoid ammonia remaining in the effluent when nitrification was active expressed a quality of organic matter very difficult to decompose, and not as well adapted to support bacteria as that in the effluent before nitrification began. — Special report for 1890, pp. 594, 595.

The results of experiments upon the application of various substances, such as peptone, egg albumen, ammonia, nitrates, etc., discussed on pages 352–365, inclusive, led to the following conclusions with respect to the bacteria: —

We have found that, if food that has been proved to be well adapted to the growth of bacteria be applied to one of these filters, when the sewage ordinarily applied is being very completely nitrified, the number of bacteria will for a time be greatly increased, and continue high until this food has passed out or is becoming nitrified; from which we may conclude that the free and albuminoid ammonia, although quite high in an effluent, when they are the residue of a much larger amount that has been burned, indicate substances that are much less able to support bacterial life than fresh organic substances that would give the same amount of free and albuminoid ammonia in solution. — Special report for 1890, pp. 596, 597.

Effect of Continuous Filtration on Bacteria.

The effect upon the number of bacteria in changing from intermittent to continuous filtration was, in No. 12, to increase and then to decrease it. In June, 1888, the number was 166. Through July, with a trap on the outlet, the number averaged 891. On July 27 the tank was filled with sewage, and continuous filtration commenced. In a week the number of bacteria in the effluent was 55,900, in three weeks it had gradually decreased to 3,540, and in two weeks more it was only 64. In the next two months, while continuous filtration continued and nitrification ceased, the number averaged less than 100. During this time there was no nitrification to kill them, but they were unable to survive the long passage of three weeks through the sand without oxygen. When nitrification ceased in No. 7, due to the surface becoming impervious to air, the quantity of water that could enter was so small that about two months were required to pass through the sand; and so long a passage without air was undoubtedly the cause of the number of bacteria being very small, although there was no nitrification. — Special report for 1890, pp. 586, 587.

Fate of the Sewage Bacteria.

Many experiments were made to determine the fate of the sewage bacteria and the source of the bacteria found in the effluents. Experiments made with Tank No. 12, in 1888, in which year analyses were made of the sewage at different depths in its passage through the filter, showed that the removal of bacteria was continuous throughout the filter, but that the greater proportion of the bacteria was eliminated in the upper layers. (Special report for 1890, p. 157.) Examinations of the sand in this and other filters showed that the accumulation of bacteria in the sand was much greater near the surface, and that the numbers decreased rapidly as the depth increased. The numbers of bacteria found in the filter sand, however, were never more than a very small fraction of the numbers which had been removed from the sewage. (Special report for 1890, pp. 59, 155, 269, 319 and 413.) By washing out the underdrains and effluent pipes, by stopping up the filter outlets and allowing them

to fill up, or by forcing city water of a known bacterial content back into the filter, and then allowing the contents to flow out with a rush, large numbers of bacteria were obtained, showing that there was a growth of bacteria upon the inside of the pipes and within the underdrains, some of which might have become detached and have appeared in the effluents.

The details of these experiments are given on pages 47, 49, 56, 57, 85, 87, 268, 269, 271 and 365 of the special report for 1890.

They showed that the number dislodged mechanically is far too small to explain the discharge of bacteria in the effluents from the tanks of coarse sand. The only alternative is to conclude that the bacteria are derived, not from the pipes or drains, but through the body of the filter itself. — Special report for 1890, p. 855.

To further test the efficiency of the filters in removing bacteria, cultures of B. prodigiosus, a species foreign to the Lawrence sewage, were mixed with the sewage applied to a number of the filters.

The results proved conclusively that B. prodigiosus passes through the tanks of coarser sand. The number of germs discharged, as compared with the number applied, was extremely small, which indicated that most of those applied had perished in the sand, precisely as those from the sewage mostly perish, during the ordinary operations of intermittent filtration. It should be observed that these experiments, proving the passage of bacteria through intermittent filters, were made several months before those of Fraenkel and Piefke upon continuous filters, and were probably the first ever made in which the passage of a particular species through a sand filter was indubitably established. It is also interesting to remark that the belief that bacteria cannot survive to pass through sand filters is shown by our experiments to be as fallacious in the case of intermittent filtration as it has been shown to be in the case of continuous filtration by the experiments of Fraenkel and Piefke. — Special report for 1890, pp. 851, 852.

Effect of Size of Material, etc., upon Removal of Bacteria.

In the preceding pages, the relation of various factors to the removal of bacteria has been discussed. The statements made there were all based on the experimental work of the first two or three years, as reported in 1890. The question of bacterial removal by intermittent filters was discussed further in the reports for 1891, 1893 and 1894, and conclusions were drawn as to the influence of the size of material, condition of the filter, etc.

The number of bacteria in the effluent of a sewage filter depends upon the size of the material and the condition of the filter. With filters of very

fine sand, such as Nos. 2 and 4, it is probable that no bacteria pass through from top to bottom. When the nitrification is very incomplete, and there has been considerable storage of organic matter in the sand, the number of bacteria in the effluent frequently increases. These bacteria, however, belong to one or more hardy species which are able to multiply within the filter. Filters Nos. 6 and 9A, when operated under the most favorable conditions, appear to allow no bacteria to pass through from top to bottom. When operated at high rates of filtration, however, a very small percentage of the applied bacteria, as a rule, passes through the filters. With materials as coarse as those in Filters Nos. 1, 5A and 15B there are always some bacteria which pass directly through the filter. The number of bacteria decreases as the distance from the point of application to the underdrains and the time taken to travel this distance increase.

With regard to seasonal effect, it is to be stated that generally speaking the winter months are the time of least efficiency, because the conditions for nitrification and other processes are then least favorable. When a filter is in good condition it is possible to obtain normal bacterial results in the winter, and as most increases in the number of bacteria in the effluent come from disarrangements of the functions of the filters, periods of unusually low bacteria removal may be found at all times of the year. — Report for 1893, p. 428.

The removal of different kinds of bacteria by the various types of filters studied in later years will be considered later.

Investigation of the Species of Bacteria in Sewage, etc.

The species of bacteria in sewage, and their significance was made the subject of a special paper by Dr. Jordan in the special report for 1890. Some condensed quotations from that paper follow:—

Lawrence sewage might naturally be expected to contain: (*a*) species present in the water used for household purposes; (*b*) species whose home is in the various substances that go to make up sewage; (*c*) species falling into sewage from the air; (*d*) species normally present in the upper layers of the soil. It is clear that no hard and fast line can be drawn between these several classes. The so-called "air bacteria" are simply those bacteria which are able to resist drying, and are probably identical with species occurring in soil and in water. The group of "water bacteria" is undoubtedly chiefly composed of species from the soil and from decaying substances. The species in these several classes are different, because their conditions of life, food, etc., are different.

So far as the conditions of life in sewage differ from conditions of life elsewhere, so far will the sewage be inhabited by species peculiarly adapted to those conditions. The chemical composition of the sewage undoubtedly debars some species. Many species also which would perhaps grow in

sterilized sewage are not able to exist in the presence of other and more powerful forms. From a broader sanitary point of view much is to be gained by descriptions of sewage bacteria. It is often essential to determine whether water has been contaminated by sewage, and in the present state of our knowledge this is generally impossible from a bacterial examination alone. It may be said, roughly, that a large number of different species of bacteria is indicative of sewage contamination. The occurrence of some few specific forms, such as Bacillus coli for example, usually indicate the presence of sewage in water.

A striking and highly remarkable circumstance is the comparative absence of micrococci from the sewage and effluents. So far as our experience has gone cocci rarely occur in sewage. Moulds are found rarely in the sewage and effluents. In the sand of the tanks they have been found to a depth of 2 inches, but seldom below that depth.

The two most common species in Lawrence sewage, so far as our experience has gone, are B. coli and the form we have called B. cloacæ. These two are always present in considerable numbers in every sample of sewage examined, and usually outnumber other forms. B. coli is a well-known species that inhabits the human alimentary canal, and would therefore be expected to occur in sewage. B. cloacæ is here described for the first time. The different forms of Proteus described by Hauser have also been frequently observed in sewage, and occasionally in the effluents and sand from sewage tanks.

The examination of the sands of the filter tanks has yielded some interesting facts. There is always a falling off in the numbers of bacteria on going from the surface to the bottom of the tank, and it is to be noted that this decrease is by no means equally distributed among all species. There are some species present in abundance in the top layers which never make their appearance in sand taken from a considerable depth. In a general way it may be said that the liquefying species are fewer in proportion at the bottom. The larger number of the species which possess the power of liquefying gelatin appear to perish before reaching the lower layers of the sand.

This, however, is not invariably the case. We have not as yet been able to trace any certain relation between the species found in the sands of the various tanks and the species found in the effluents from those tanks. All the species found in the sands have at some time or other been found in the effluents. On the other hand, some species are found in the effluents which have never been detected in samples of sand.

The study of the sewage bacteria also throws light upon the question as to whether or not the bacteria come through the sand. Certain tanks — as Tank No. I and Tank No. VI — have shown at times unmistakable relations between the species found in the effluents and the species normally present in Lawrence sewage, — Proteus, B. cloacæ, B. coli commune, *et al.*, being found in abundance in the effluents. In Tank No. II, on the other hand, when in its best condition, the few species occurring in the effluent are such as might easily come from the air. — Special report for 1890, pp. 822-826.

A very complete description, as far as the bacteriological methods then in vogue would allow, of twelve species common in sewage, of which nine were new species, is appended to Dr. Jordan's report. (Special report for 1890, pp. 830–844.)

Studies of the Bacteria of Nitrification.

In the belief that nitrification was due to a specific variety of bacterium, attempts were made to isolate the nitrifying organism, and after repeated trials pure cultures were obtained which were able to convert ammonia to nitrates, although this process proceeded very slowly. These experiments demonstrated, however, that the organisms of nitrification were present in all natural waters, soils, etc. (These experiments are described in a special paper by Dr. Jordan and Mrs. Ellen H. Richards, on pages 865–881 of the special report for 1890.) The very slow nitrification of the ammonia by pure culture was not understood at the time. At the present time, nitrification, especially the rapid nitrification which occurs in some sewage filters, is generally believed to result from the associative action of a number of species of bacteria, any one of which would produce results but slowly.

Fate of the Microscopical Organisms.

During the first five years, frequent microscopical analyses were made of the sewage applied to, of the effluents from and of the material in the various filters, to determine whether the organisms found in the effluents passed through the filters, or came from growths in the outlet pipes.

The microscopical organisms, such as yeast, Leptothrix, the infusoria, the algæ, etc., occurring in sewage appear to perish ordinarily in the filters. Some of the simplest forms, such as yeast and Chlorococcus, moving with the most forward particles of the sewage, may, when the sewage is applied to a tank of coarse sand after a considerable interval, pass by the films of liquid held upon or between the sand grains, and, displacing the air, sink quite rapidly to the floor of the tank. Furthermore, the spores or ova of these micro-organisms, which are usually smaller and better able to resist unfavorable conditions, may survive and escape from the filters when the adult forms are detained and destroyed. On the other hand, the extremely small numbers of these organisms in the effluents, their complete absence from the body of the filtering material of the several tanks, the direct evidence of flourishing animal and vegetable life in the underdrains, etc., obtained by examination of the drains, the results obtained by washing out the underdrains and discharge pipes of certain tanks, and the character of the fauna and flora of the effluents, which indicated their origin in the drains, pipes, etc., all, taken together, proved that very few if any of the microscopical organisms applied

in the sewage survived to escape in the effluents. Moreover, studies of the layers of the tanks proved that these organisms are destroyed soon after they pass below the surface. — Special report for 1890, pp. 845, 846.

Species of Bacteria in Septic Sewage.

During the years 1896–99 the special bacteriological investigations were devoted to the determination of the kinds of bacteria in septic sewage and in the effluents from filters operated with septic sewage. Twenty species of bacteria were found to be of common occurrence in samples of this class, and 8 of these were found to be present in from 25 to 100 per cent. of all samples examined. One species alone was found to constitute from 12 to 17 per cent. of the bacteria in all of the samples. In these studies determinations were made also of the numbers of bacteria liquefying gelatin and of the numbers developing at body temperature, and in reporting the results, special attention was called to the significance of the body temperature counts, which will be discussed later. (Report for 1904, pp. 231, 232.)

Passage of Spores through Filters of Coarse Material.

During 1901 studies were made of a few of the applied sewages and effluents from filters of coarse materials, the investigations at this time being devoted to a determination of the ratio of liquefying bacteria, spores and B. coli to the total number of bacteria. The significance of the B. coli determinations will be more fully discussed later.

The studies of the presence of spore-bearing types were undertaken to determine in a measure the fate of spore-bearing disease germs, such as the bacillus of anthrax. The results of these studies showed clearly that, while there is a material reduction in the total number of bacteria and in the number of bacteria of non-spore-bearing types in the passage of sewage through a septic tank and through contact and trickling filters, there is no perceptible reduction in the numbers of spore-bearing bacteria. — Report for 1904, p. 233.

Removal of B. Coli by Sewage Filters.

Beginning in 1902, studies were made of the passage of B. coli through sewage filters, and the results of the first three years of those studies were summarized in the report for 1904.

While B. coli, as has been pointed out many times in previous reports, cannot be considered a disease germ, nevertheless, as regards length of life under a variety of conditions, it is very similar to the bacillus of typhoid fever, and from its study in sewage effluents inferences may be drawn as to what would be the effectiveness of these filters in removing that organism. From the results obtained it is evident that sewage filters of coarse materials,

operating at high rates, will not remove all the bacteria of the colon type. On the other hand, intermittent sand filters may remove all, or at least a large proportion, of these germs at certain times. The large Filters Nos. 2 and 4, filled with fine sand and operated at low rates, have been particularly efficient in this respect, B. coli being usually absent from one cubic centimeter samples of the effluents from these filters. The removal of B. coli during treatment by different methods has been as follows: Septic Tank A removed an average of 46 per cent. of the B. coli. Of the sand filters receiving raw sewage, Filters Nos. 2 and 4 removed practically all of the B. coli; Filters Nos. 6 and 10 removed over 99 per cent.; Filter No. 9A removed over 98 per cent.; and Filters Nos. 1 and 5 removed about 97 per cent. of the B. coli. Filter No. 100, a sand filter, removed over 98 per cent. of the B. coli from the septic sewage with which it was operated. Of the contact filters operating with raw sewage, Filter No. 221 removed nearly 49 per cent., and Filter No. 176 over 71 per cent.; while Filter No. 103, which received septic sewage, removed over 76 per cent., and Filter No. 175, which received strained sewage, removed only a small percentage of the B. coli. Both of the intermittent-continuous or trickling filters, constructed of coarse materials, and operated with raw sewage at high rates, showed a high percentage removal, Filter No. 135 removing over 99 per cent. and Filter No. 136 about 97 per cent. — Report for 1904, pp. 233–235.

The tests for B. coli were continued as a part of the routine analyses, and a discussion of the results obtained in the following years will be found further on.

Occurrence of Thermophylic Bacteria in Sewage and Sewage Effluents.

During 1905 and 1906 an investigation was made to determine the occurrence and numbers of bacteria growing on culture media at a temperature of 50° C. In the investigation were included sewage, septic sewage and the effluents of the various types of sewage filters. Bacteria capable of development at this or higher temperatures, usually called thermophylic bacteria, had been isolated previously from sewage by a number of investigators, and had been assumed to have some sanitary significance, but up to this time no systematic investigations had been made to determine in what numbers they might be present. The results of the determinations showed that bacteria of this type were of common occurrence in sewage and in the effluents from filters constructed of coarse materials, but that, in the effluents from intermittent filters of fine sand, in which an active nitrification was taking place, they were much less numerous. For example; in sewage and in the effluents from trickling filters such bacteria were to be found in practically all samples; in the effluents from contact filters they were found in about 80 per cent. of the samples; in the effluents of intermittent filters of coarse sand, such as Filters Nos. 1 and 6, they were present in about 60 per cent. of the

samples, while in effluents from Filters Nos. 2 and 4, constructed of very fine sand, they were found only occasionally. The numbers of thermophylic bacteria in the Lawrence sewage averaged about 20,000 per cubic centimeter, in the septic sewage about 400, in the effluents from trickling filters about 2,000, in the effluents from contact filters from 500 to 8,000, and in the effluents from sand filters from 0 to 1,400. These numbers constituted generally less than 1 per cent. of the total number of bacteria determined in the samples, although in a few cases this percentage ran as high as 8 or 10 per cent. for some samples, notably in the effluent from sand Filter No. 1 and the effluents from contact Filters Nos. 175 and 176.

It is noticeable that the 50° C. bacteria in the effluents from the contact Filters Nos. 175 and 176 were higher than in the regular sewage which was applied to those filters, and the numbers in the effluent of contact Filter No. 251 were larger than in the septic sewage with which it was operated. On the other hand, the numbers in the effluents from the trickling filters were small, and this type of bacteria was either entirely lacking, or present in insignificant numbers, in the effluents from the sand filters.

The occurrence of 50° acid-producing bacteria is also significant, this type of organism being absent from the effluents from three out of four of the intermittent sand filters, and practically absent from the fourth, while they were present in greater or smaller numbers in the sewages and in the effluents from the contact and trickling filters, through which the sewage passed more rapidly. — Report for 1906, pp. 330–335.

Bacterial Incubation Tests.

It was noted in the early reports that the numbers of bacteria in sewage and the effluents from sewage filters increased if those samples were allowed to stand in the laboratory, and in the study of manufacturing wastes (report for 1896, p. 455) this test was applied to determine whether such wastes were antiseptic. Similar tests have been applied at the station to samples of all kinds, but the results have generally been so varied that no definite conclusions could be drawn from them, and they have not been published. Some experiments made in 1906, however, threw some light on the relation between the character of a water and its bacterial content. These tests were similar to the incubation or putrescibility tests quite commonly applied to effluents of filters of coarse materials. The samples were allowed to stand for twenty-four hours at 40° C., and determinations were made of the numbers of bacteria at 20° and 40° C. before and after incubation.

In the sewages the total numbers of bacteria after incubation averaged one and one-half to five times as great as the numbers before incubation, the largest increase being in the septic sewage. A similar increase was

noted in the 40° C. counts, the numbers in the Andover sewage increasing to about seven times the initial number. Much the same results were obtained with the effluents from contact filters, although the increase in numbers was generally slightly larger than in the case of the sewages. In the trickling filter samples a much greater change occurred. In the effluents from Filters Nos. 135 and 136, which were giving highly nitrified effluents, although rich in organic matter, the bacteria after incubation averaged about fifty times the number in the samples when first collected. On the other hand, in the case of effluents from intermittent sand filters, also highly nitrified, but containing a relatively small amount of organic matter, a reduction of 70 to 90 per cent. in the bacteria occurred during incubation. These results cannot but indicate that there was a great difference in the character of the organic matter serving as food for the bacteria in samples of the various types. (Report for 1906, pp. 346, 347.)

Relative Removal of Bacteria of Different Types as determined by Counts at 20° and 40° C.

During 1906 and 1907, in addition to determinations of numbers of bacteria on agar plates incubated four days at 20° C., determinations were made also of the total numbers and of the numbers producing acid fermentation of lactose on litmus-lactose-agar plates incubated eighteen hours at 40° C. The numbers of bacteria producing acid fermentation of lactose at the higher temperature consist largely of B. coli, but also include a few species of similar origin, such as B. cloacæ and the sewage streptococci. For convenience, this group of bacteria has been usually called B. coli in reporting quantitative results of the analyses of sewage and sewage effluents, and their significance has been established by many investigations at the Lawrence Experiment Station and elsewhere. The total count at 40° C. has a similar significance, but includes other species, also mostly of intestinal origin.

The studies in 1906 showed that there is an approximately constant ratio between the total counts at 20° and 40° C., and between the total numbers developing at 40° C. and the acid producers, this being true for all sewages and effluents from sewage filters under normal conditions. This being true, the bacterial removals computed from the different counts should be similar, and the determinations at the two temperatures act as a check upon one another. Since the 40° C. counts show more nearly than do the total numbers determined at 20° C. the numbers of bacteria of intestinal origin whose removal is of the most importance, the results obtained at this temperature are more accurate in showing the hygienic efficiency of any filtration system, and should be preferred to the older 20° C. counts should the two methods fail to give concordant

results. Another advantage of the use of the 40° C. counts is that they are available much sooner than are the results obtained at the lower temperature, and the control of filtration processes requiring good bacterial efficiency is thereby greatly facilitated. All these points were discussed on pages 335–338 of the report for 1906, and tables were given showing the relative numbers obtained by counts at the two temperatures. In the report for 1907, on pages 235–238, the results of the counts at both temperatures obtained during that year were tabulated, and the removal of bacteria by different types of filters as computed from the different results were compared and discussed. During 1908 the differential counts upon all samples were continued as a part of the routine analyses. The average results of the three years' analyses by these methods are shown in the table on pages 514 and 515, and from them much may be learned as to the removal of the different types of bacteria by various methods of sewage purification.

Three methods of preliminary treatment of sewage were in use throughout the three years, these being sedimentation, straining and septic tanks. Of these, straining was the most effective and sedimentation the least efficient in removing all types of bacteria. The relative removal of different types of bacteria by these systems varied somewhat. Septic Tank A removed all types equally well. Sedimentation removed a greater proportion of the 40° C. bacteria and of B. coli than of the total bacteria, while the reverse was true in the case of Strainer E, in which the highest percentage removal was shown by the counts of total bacteria.

All of the intermittent sand filters removed over 99 per cent. of bacteria of all types, with the single exception of Filter No. 6 which showed a bacterial removal of the 40° C. types of about 98.8 per cent. The most efficient of the large sand filters were Nos. 2 and 4, which removed about 99.98 per cent. of the total bacteria and 99.99 per cent. of the bacteria determined at 40° C., including the B. coli. The intermittent filters located within the station were slightly more efficient than those containing sand of similar grades out of doors, and Filter No. 315, containing 10 feet in depth of sand, was slightly more efficient than its companion filters of lesser depth.

The bacterial efficiency of Filter No. 176 was much greater than of any of the other contact filters, about 73 per cent. of the total bacteria and over 62 per cent. of the bacteria determined at 40° C. being eliminated. This filter had become badly clogged during the latter years of its operation, and the bacterial efficiency may have been increased in consequence. Its companion, Filter No. 175, showed an average removal of total bacteria of less than 25 per cent. and a removal of the 40° C. types of only 30 to 31 per cent. The efficiency of Filter No. 251

was slightly greater than that of Filter No. 175 when computed from the 20° C. counts, and slightly less than that of the same filter when computed from the 40° C. counts. Filter No. 221 removed over 47 per cent. of the total bacteria and 35 per cent. and 44 per cent., respectively, of the total 40° C. bacteria and of the B. coli, while Filter No. 237, to which the effluent from Filter No. 221 was applied, continued the work by removing about 43 per cent. of the bacteria remaining after contact in the primary filter, and 47 per cent. and 42 per cent., respectively, of the total bacteria growing at 40° C. and of the B. coli.

The efficiencies of the different trickling filters varied between 64 and 97 per cent., judging from the total bacteria; between 73 and 95 per cent. when based on the total counts at 40° C., and between 75 and 96 per cent. when computed from the numbers of B. coli. The two deep filters, Nos. 135 and 136, were much more effective in eliminating bacteria of all types than were the filters containing less depth of material. Similar results are shown by a comparison of the efficiencies of Filters Nos. 247 and 248, the bacterial removal by the deeper filter, No. 248, being distinctly greater than that by Filter No. 247.

The effluents from trickling Filters Nos. 135 and 136 were passed through a settling tank and then applied to the secondary sand Filters Nos. 224, 249 and 250. There was some growth of bacteria in the feed tanks for these filters so that the efficiency of sedimentation is concealed. The efficiency of the three secondary filters varied between 87 and 98 per cent., judging from the counts of total bacteria at 20°C.; between 81 and 98 per cent., based on the total numbers determined at 40°C.; and between 86 and 98 per cent. as shown by the removal of B. coli. Filter No. 224 was the most efficient and Filter No. 249 the least. The removals computed from all three counts were practically identical for two of the filters, while the difference in removal of the different types by the other filter was less than 6 per cent.

Considering the various combinations of preliminary treatments and filters as systems or units, the intermittent sand filters operated at rates of 20,000 to 150,000 gallons per acre daily were most efficient, with bacterial removals of over 99 per cent. Next in point of efficiency are the double filtration systems, in which the sewage was settled, passed through trickling Filters Nos. 135 and 136 at rates of about 1,500,000 to 2,500,000 gallons per acre daily and the combined effluents from these filters, after passing through settling basins were then refiltered through sand Filters Nos. 224, 249 and 250 at rates of 500,000 to 700,000 gallons per acre daily. The systems represented by Filters Nos. 224 and 250 showed a bacterial removal of over 99 per cent. of all the types of bacteria, while that including Filter No. 249 showed an efficiency of over 97 per cent. as shown by counts at 20° C., and of over 99 per cent. when computed

from the 40°C. determinations. The net rates of these double filtration systems varied between 400,000 and 500,000 gallons per acre daily. Trickling Filters Nos. 135 and 136, to which settled sewage was applied at rates three to five times as great, were only slightly less efficient in eliminating bacteria than the double filtration systems of which they served as primary filters, both showing bacterial removals of 96 to 97 per cent. The double contact system, including Filter No. 221, to which settled sewage was applied and whose effluent was applied to Filter No. 237, had an efficiency of only 77 to 78 per cent., much less than the sand or trickling filters, in which oxidation processes were more complete. The single contact systems were still less effective, septic treatment and Filter No. 251 having an efficiency of only 53 to 55 per cent., sedimentation and Filter No. 221 having an efficiency of 58 to 62 per cent., and straining, followed by contact action in Filter No. 175, having an efficiency of 62 to 64 per cent.

Table showing Relative Removal of 20° and 40° C. Bacteria and of B. Coli by Sewage Filters.

Untreated Sewage.

	Bacteria per Cubic Centimeter.		B. Coli per Cubic Centimeter.	Per Cent. Removed.		
				Bacteria.		B. Coli.
	20°C.	40°C.		20°C.	40°C.	
Lawrence station sewage,	1,189,600	392,900	335,300	-	-	-
Regular sewage,	1,112,400	303,800	250,400	-	-	-
Andover sewage,	2,263,000	388,300	308,400	-	-	-
Sewage for Filter No. 306,[1]	544,600	164,200	184,800	-	-	-
Preliminary Treatments.						
Lawrence settled sewage,	843,700	196,400	166,600	24.00	35.30	33.30
Andover settled sewage,	1,297,000	274,000	229,000	42.50	28.40	34.00
Strained sewage,	517,900	162,400	132,400	52.40	46.50	47.10
Septic sewage,	727,300	185,500	149,600	41.90	42.00	43.60
Intermittent Filters.						
Filter No. 1,	5,400	2,500	2,200	99.44	99.04	98.97
2,	235	20	17	99.98	99.99	99.99
4,	170	28	8	99.98	99.99	99.99
5C,	4,700	1,575	1,340	99.58	99.48	99.46
6,	6,400	3,120	2,500	99.33	98.80	98.82
9A,	2,000	580	480	99.79	99.78	99.80
10,	1,260	310	230	99.87	99.88	99.89
305,	3,400	510	425	99.69	99.83	99.83
306,	3,250	195	110	99.40	99.88	99.92
312,	850	6	5	99.92	99.99	99.99
313,	1,660	90	75	99.85	99.97	99.97
314,	2,240	695	655	99.80	99.77	99.74
315,	2,680	480	400	99.76	99.84	99.84
316,	350	8	0	99.97	99.99	100.00

[1] Dilute sewage.

Table showing Relative Removal of 20° and 40° C. Bacteria and of B. Coli by Sewage Filters — Concluded.

Trickling Filters.

	Bacteria per Cubic Centimeter.		B. Coli per Cubic Centimeter.	Per Cent. Removed.		
				Bacteria.		B. Coli.
	20°C.	40°C.		20°C.	40°C.	
Filter No. 135,	29,300	9,000	7,700	96.53	95.42	95.40
136,	40,500	7,700	6,500	95.20	96.08	96.11
222,[1]	458,800	33,700	31,400	64.70	87.70	86.30
233,	302,200	53,300	41,700	64.20	72.80	75.00
235,	137,400	39,000	31,100	88.80	80.10	81.40
247,	234,800	48,500	36,600	72.20	75.30	78.10
248,	130,400	11,300	8,500	84.60	93.98	94.92

Contact Filters.

Filter No. 175,	395,700	112,700	91,000	23.60	30.20	31.10
176,	229,000	73,200	63,500	72.80	62.70	62.00
221,	445,600	126,800	93,800	47.20	35.20	44.00
251,	521,900	136,900	113,600	28.20	26.30	24.00

Secondary Filters.

Filter No. 224,[2]	4,600	240	100	97.94	98.41	98.63
237,[3]	256,100	67,400	54,000	42.60	47.00	42.40
249,[2]	29,700	2,909	1,060	86.70	80.80	85.50
250,[3]	10,400	810	430	95.34	94.65	94.10

[1] Operated with Andover settled sewage. [2] Intermittent filters. [3] Contact filter.

Nitrification and Bacteria.

In the early studies of intermittent filters it was observed that when sewage is first applied to a sand filter the reduction in numbers of bacteria is relatively small, the action being that of straining only. As the biochemical processes become established in the filter the numbers of bacteria in the effluent decrease, and, with the starting of nitrification, a marked increase is to be noted in the removal of bacteria. This observation has been confirmed by the results of practically all intermittent filters since that time. With contact and trickling filters constructed of coarse materials and operated at high rates, however, this does not hold at all times, and while the results obtained with some of these filters may appear to follow the rule, the exceptions are numerous. This is true both in respect to prenitrification results and as regards the effect of the starting of nitrification. In the following table are shown the average numbers of bacteria and the amount of nitrates in the effluents from three typical contact and trickling filters during the first five months they were operated while the process of nitrification was being estab-

lished. It is to be noticed that one filter of each type is shown in which an increase in nitrification is accompanied by a decrease in bacteria, while two other filters of each type show no such effect. This is about the proportion in which similar results would be found if all of the many contact and trickling filters which have been operated at Lawrence during the past ten years were included in the tabulation, the results selected being typical ones representing fairly each group.

Effect of Beginning of Nitrification on Numbers of Bacteria.

Month of Operation.	Contact Filters.			Trickling Filters.		
	Filter Nos.	Nitrates.	Bacteria per Cubic Centimeter.	Filter Nos.	Nitrates.	Bacteria per Cubic Centimeter.
1, ...	103	0.02	97,800	134	0.01	581,000
2, ...	103	0.05	59,400	134	0.17	158,800
3, ...	103	1.29	41,200	134	0.13	139,000
4, ...	103	2.07	22,600	134	3.68	66,500
5, ...	103	2.10	13,500	134	1.61	25,900
1, ...	175	0.06	104,000	234	0.02	706,000
2, ...	175	0.86	48,000	234	0.32	650,000
3, ...	175	1.20	240,000	234	0.97	1,000,000
4, ...	175	0.87	193,000	234	2.05	325,000
5, ...	175	2.24	193,000	234	0.93	790,000
1, ...	176	0.20	214,000	82	0.05	561,000
2, ...	176	0.50	287,000	82	0.91	412,000
3, ...	176	0.87	194,000	82	2.13	522,000
4, ...	176	0.81	531,000	82	1.75	299,000
5, ...	176	2.53	244,000	82	2.23	680,000

The conclusions that the numbers of bacteria decrease with the completeness of nitrification in intermittent filters, made in the special report for 1890 as before quoted, were based on the results of the operation of a few sand filters for a limited period only. The results of the operation of the large intermittent sand filters, however, during their entire period have confirmed this statement, and it may be said in general that the greater the amount of nitrification the smaller the number of bacteria in the effluent. This is true, also, of the trickling filters, in which the process of purification by oxidation is similar to that in intermittent filters. With contact filters, however, the nitrates formed during the oxidation stage may be reduced while the sewage is standing in the filter, with the result

that the effect of nitrification upon the bacteria is concealed if such a condition results. In the following table are shown the average bacterial results from four intermittent sand filters which have been operated for about twenty-one years, and of three contact and two trickling filters which have been operated from seven to ten years each, these results being obtained by averaging the numbers of bacteria in the effluents at such times as they contained various amounts of nitrates. The intermittent filters, almost without exception, show a gradual reduction in the numbers of bacteria as the amount of nitrates in the effluent increased. This reduction bears no relation to the size of the material or the numbers of bacteria, the effect with Filters Nos. 2 and 4, of extremely fine sand, being the same as with Filters Nos. 1 and 6, of very coarse sand. Similar results were observed with other intermittent filters. Much the same effect is noticed in the trickling Filters Nos. 135 and 136, and the results seem to be typical for this class. With the contact filters, No. 103 follows the same general law. With Filters Nos. 175 and 176, however, this result is not noted, and the results from other contact filters show that they follow the rule illustrated by Filters Nos. 175 and 176 rather than that illustrated by No. 103, and by the strictly aerobic types of filters. The individual results from which these figures were compiled show that the nitrification and bacterial curves do not necessarily coincide. That is to say, if the curves showing the numbers of bacteria and nitrates in the effluents of any of these filters were plotted month by month or week by week, an increase in nitrates might correspond with a decrease in the numbers of bacteria, or the reverse. The averages as tabulated, however, show that the removal of bacteria is greatest in filters of the aerobic type when nitrification is high rather than when nitrification is low, and the same result would be noted in the general upward or downward tendency of the curves were the results plotted.

Table showing Relation between Numbers of Bacteria and Nitrates in Effluents from Filters of Different Types.

Filter Nos.	Nitrates (Parts per 100,000).						
	Below 1.	1-2.	2-3.	3-4.	4-5.	5-6.	Above 6.
1, . . .	99,800	63,100	23,400	18,800	16,200	21,500	1,600
2, . . .	1,400	875	275	205	235	65	160
4, . . .	500	200	60	83	281	35	37
6, . . .	26,000	15,300	11,800	8,700	4,600	8,700	3,300
103, . . .	321,100	198,000	78,000	84,900	-	-	-
175, . . .	270,000	480,000	470,000	449,000	-	-	-
176, . . .	336,400	593,000	244,000	-	-	-	-
135, . . .	268,000	82,600	40,500	35,900	35,400	31,200	-
136, . . .	167,700	67,100	66,400	31,800	40,300	39,000	11,800

In an experiment made with Filter No. 14 in 1890 it was shown that the nitrates increase and the bacteria decrease as the sewage flows through the successive layers of an intermittent sand filter. This was proved to be true also in the case of trickling filters by the operation of Filter No. 131 in 1899. In this filter the material was separated into six layers, through which the sewage flowed consecutively, and provision was made for obtaining samples between the various layers as well as at the outlet. The analyses of a number of series of samples from different portions of this filter were given on page 435 of the report for 1899, the nitrates and bacteria in one series being as follows:—

	Bacteria per Cubic Centimeter.	Per Cent. Removed.	Nitrates (Parts per 100,000).
Applied sewage,	3,750,000	-	-
Section 1,	617,000	83.50	0.11
Section 2,	303,000	91.92	0.25
Section 3,	153,000	95.93	0.53
Section 4,	126,000	96.65	0.81
Section 5,	96,000	97.24	1.06
Outlet,	55,000	98.54	1.11

Hygienic Efficiency of the Principal Filters of Different Types.

In the foregoing pages statistics as to the removal of bacteria by intermittent sand filters during the earlier years of the experiments, and the effect of various conditions, such as nitrification, winter weather, etc., upon the numbers of bacteria in the effluents, have been quoted and discussed. The removal of specific types of bacteria, such as B. coli, thermophylic bacteria and the types determined at 40° C., has also been considered. The determinations of these latter types extend over a comparatively few years. Determinations of the total bacteria at 20° C., however, extend over the whole period of operation of all of the filters, and much may be learned by comparing the bacterial efficiencies of these different filters, which have been operated for many years. In considering hygienic efficiency, attention should be given not only to the percentage removal of bacteria but also to the numbers of bacteria in the effluent, since it is by these numbers that effluents of sewage filters are compared with waters of other classes.

In the table on page 524 are shown the average numbers of bacteria in the effluents from a number of the principal filters of the various types during the whole period of operation, and the average percentage removal

of bacteria. The table shows also the maximum and minimum average numbers during any one year and the maximum and minimum average yearly removal. From this table it is evident that the removal of bacteria by the intermittent filters, except in a very few instances, was well over 99 per cent. The smallest removal during the whole period of operation was that by cinder Filter No. 80, which had an average removal of 89 per cent. and a minimum removal of 73 per cent. In one of its three years of operation, however, this filter had a removal of practically 100 per cent., the low value being shown during the first year of operation, including the period before nitrification had become established. Filter No. 5B, also constructed of cinders, was operated for eight years with an average bacterial removal of 98 per cent., the smallest removal in any one year being nearly 97 per cent. Filter No. 5A, composed of fine gravel with an effective size of 1.40 millimeters, also showed a comparatively poor bacterial removal, the average during the eight years of its operation being about 95 per cent., the removal in one year falling as low as 77 per cent. Filter No. 1, of coarse sand having an effective size of 0.48 millimeter, had an average removal of 98 per cent., the smallest removal during any one year being 91.3 per cent. Filter No. 6, containing sand of an effective size of 0.35 millimeter, had an average efficiency of 99.4 per cent., and the smallest removal during any one year was 98.7 per cent. Filter No. 9A, of a still finer sand, 0.17 millimeter effective size, had an average removal of about 99.5 per cent. and a minimum removal of 98.5 per cent. Filters Nos. 2 and 4, of extremely fine sand, were by far the most efficient, having average removal values of practically 100 per cent. each, and never falling below 99.77 per cent. in any one year. Considering the bacteriological results from the point of view of the numbers of bacteria contained in the effluents, none of the effluents from these intermittent filters averaged less than 100 bacteria per cubic centimeter, and only three averaged less than 500 per cubic centimeter, these being Filters Nos. 2, 4 and 141, all containing fine sand. The effluent from Filter No. 141 averaged only 150 bacteria per cubic centimeter during the one year which it was operated. Filters Nos. 2 and 4 yielded effluents which averaged 490 and 220 bacteria per cubic centimeter, respectively, during the twenty-one years they were operated, the smallest number during any one year being 9 bacteria per cubic centimeter for Filter No. 4 and 32 per cubic centimeter for Filter No. 2. Cinder Filter No. 80 compares favorably with Filters Nos. 2 and 4 during one of its three years of operation, yielding an effluent containing only 36 bacteria per cubic centimeter. Filters Nos. 6, 9A, 306, 313, 316 and 14A all had periods averaging one year or more when their effluents contained less than 1,000 bacteria per cubic centimeter, although the averages during

their whole period of operation were much greater. An interesting point is to be noticed in the results obtained with Filters Nos. 305 and 306. The former always received the regular Lawrence sewage, while the latter was flooded with sewage diluted with an equal volume of canal water. Both as regards removal of bacteria and numbers of bacteria in the effluent the results are practically the same, the filter receiving dilute sewage giving slightly the better effluent, but the difference is so small as to be negligible. An inspection of the monthly averages of the large intermittent sand filters shows that Filter No. 4 yielded an effluent containing less than 100 bacteria per cubic centimeter during one hundred and seventy-two of the two hundred and forty-nine months it was operated, or 69 per cent. of the time, and Filter No. 2 an effluent of similar quality in one hundred and forty-five months, or 58 per cent. of the time. Filter No. 9, containing a medium fine sand, gave an effluent containing less than 100 bacteria per cubic centimeter in twenty-seven of the two hundred and thirteen months it was operated, or about 13 per cent. of the time, while Filters Nos. 1 and 6, of coarse material, gave effluents of this quality only 1 to 3 per cent. of the time.

A further inspection of the monthly averages, however, reveals that while the effluents from Filters Nos. 2 and 4 contained less than 100 bacteria per cubic centimeter during the greater part of the time, these effluents occasionally contained more than 1,000 bacteria per cubic centimeter. These results, as well as the averages previously quoted, confirm the statements in the early reports, that only by the use of very fine materials can drinking water effluents be obtained. Those statements must be qualified, however, by saying that, while effluents of this high bacterial quality may be obtained part of the time, at other times they may contain very much larger numbers of bacteria. The per cent. of time the numbers of bacteria in the effluents from these large intermittent sand filters were less than 100 and less than 1,000 per cubic centimeter, is shown in the following table: —

Filter Nos.	Months Operated.	Per Cent. of Time Bacteria in Effluent averaged Less than —	
		100 per Cubic Centimeter.	1,000 per Cubic Centimeter.
1, ...	248	1.2	4.8
2, ...	249	58.2	87.7
4, ...	249	68.7	96.0
6, ...	248	2.8	14.9
9A, ...	213	12.7	43.7

Practically all of these filters contained about 5 feet in depth of filter material. With Filters Nos. 313 and 316 it is possible to compare the effect of a greater depth of material. These two filters were constructed of the same material and were operated under identical conditions, but the former was 5 feet deep and the latter 10 feet. The average removal of bacteria by both of these filters was over 99 per cent. In the effluent from the 10-foot filter, however, the numbers of bacteria averaged 7,900 per cubic centimeter as compared with 9,700 in the effluent from the 5-foot filter. The smallest numbers of bacteria in the effluents during any one of the three years during which these filters were operated were 115 for the deep filter and 800 for the 5-foot filter.

Three intermittent filters were operated with septic sewage, one with settled sewage and one with strained sewage. One of the three operated with septic sewage, Filter No. 116, containing the finest sand, gave the most satisfactory effluent, that is, the lowest numbers of bacteria and the highest percentage removal, while Filter No. 100, containing the coarsest sand, was the least efficient of the three. The material in Filter No. 32, which received settled sewage, and Filter No. 14A, which received strained sewage, was practically the same as that in Filter No. 116, although Filter No. 32 was only 2½ feet deep, while the other filters were 5 feet deep. Comparing these filters with those of similar material but receiving untreated sewage, it is seen that, while the percentage removal of bacteria was usually somewhat less, the actual numbers of bacteria were also in general considerably less in the effluents from filters operated with treated sewage. Of the three filters named, Filter No. 116, receiving septic sewage, averaged lowest in numbers of bacteria, while Filter No. 32, receiving settled sewage, averaged the highest. The best yearly average of Filter No. 14A, however, was considerably better than that of Filter No. 116.

Four of the intermittent filters in the list were operated as secondary filters, three of them, Nos. 224, 249 and 250, receiving the effluents from trickling Filters Nos. 135 and 136, while the other, No. 12A, received the effluent from Filters Nos. 15B and 16B, which were operated essentially as trickling filters. Of these four filters, No. 12A, containing the finest sand, gave unquestionably the best effluent from a bacterial point of view. The average removal of bacteria by Filter No. 12A during its six years of operation was 99.4 per cent., the smallest removal in any one year being 98.9 per cent. The best result of any other secondary filter was that of Filter No. 224, which during one year had an average bacterial removal of 99.3 per cent. and, for the five years of its operation, an average of 89.4 per cent. The effluent from Filter No. 12A con-

tained on an average only 1,500 bacteria per cubic centimeter, the maximum number in any one year being 2,100 and the minimum 485 per cubic centimeter. During one year the effluent from Filter No. 224 averaged only 1,300 bacteria per cubic centimeter, but the average of the whole five years of its operation was nearly 36,000, and in one year it was over 94,000 per cubic centimeter. Filters Nos. 249 and 250 were of much coarser sand than Filter No. 224, and equal bacterial efficiencies could not be expected. Nevertheless, Filter No. 249 had an average bacterial removal of over 91 per cent., as compared with 89.4 per cent. for Filter No. 224. The minimum removal by Filter No. 249, however, was only about 47 per cent., as compared with 82 per cent. for Filter No. 224. Filter No. 250, of the same depth and material as Filter No. 249, but operated in a slightly different manner, was considerably less efficient. Comparing the effluents from the secondary filters, operated with sewage which had been partially purified by trickling filters, with those from intermittent filters receiving raw sewage, it is to be noted that in almost every instance the numbers of bacteria were much greater after the sewage had passed through the double filtration process than when filtered through a single intermittent filter.

Considered both from the standpoint of bacterial removal and from that of the numbers of bacteria, the effluents from both contact and trickling filters were far less satisfactory than those from the intermittent filters, although the results with the trickling filters were somewhat better than those with the contact filters. Five of the eight trickling filters shown had a greater bacterial removal than any of the five contact filters, and the other three had a greater removal than four of these contact filters. The greatest bacterial efficiency was obtained with Filters Nos. 135 and 136, which had an average removal of about 93.7 per cent. during nine years of operation. Filter No. 135 had the greatest efficiency during any one year, with a removal of approximately 99 per cent., Filter No. 136 being second, with a removal of 97.5 per cent. It is interesting to compare the results obtained with Filters Nos. 15B and 16B, operated during the early days of the station, with the more recent trickling filters. The rates at which the two former filters were operated were considerably less than those of the modern filters and in addition they were mechanically aerated. On the other hand, they were only about one-half as deep as Filters Nos. 135 and 136. The average removal of bacteria by Filters Nos. 15B and 16B was 90 and 89 per cent., respectively, the maximum removal being about 96 per cent. for each and the minimum removal 74 and 72 per cent., respectively. As regards the numbers of bacteria in the effluents, Filter No. 136 was most efficient, with an average of 71,500 bacteria per cubic centimeter, the minimum

number in any one year being 41,300 per cubic centimeter. The effluent from Filter No. 135 averaged 101,000 bacteria per cubic centimeter, and during one year contained only about 26,500 per cubic centimeter. The effluents from Filters Nos. 15B and 16B averaged 242,000 and 271,000 bacteria, respectively, the minimum numbers during any one year being 153,000 for Filter No. 16B and 208,000 for Filter No. 15B. Filter No. 247, containing practically the same grade of material as Filters Nos. 135, 136 and 248, but of less depth, yielded a much less satisfactory effluent, from a bacteriological standpoint, than the filters containing a greater depth of material. The results obtained with both of the filters constructed of clinker were practically the same. In their best year the effluents from these two filters compared favorably with the other trickling filter effluents, but the average results were considerably below those of the stone and gravel filters.

The best of the contact filters, in point of bacterial efficiency, was Filter No. 103, operated with septic sewage, which had an average removal of 82 per cent. and a maximum removal during one year of 92 per cent. The average number of bacteria in the effluent from this filter during the whole period was 158,000, a smaller number than that of any of the trickling filters shown, except Filters Nos. 135 and 136. The minimum numbers of bacteria in the effluent from this filter in one year were 44,100. Contact Filters Nos. 175 and 176 showed practically the same bacterial removal — 76 per cent. Filter No. 175, receiving strained sewage, however, gave an effluent of more uniform quality than did its companion filter which received untreated sewage at one period and settled sewage at another. The minimum removal by Filter No. 175 was only 11.7 per cent., while the smallest removal by Filter No. 176 was 64.7 per cent. The average numbers of bacteria in the effluent from these two filters were practically the same. The minimum numbers for any one year were 131,000 for Filter No. 175 and 195,000 for Filter No. 176. Filters Nos. 221 and 251 were far less satisfactory than the other contact filters mentioned. The average removal of bacteria by these two filters was 60.6 per cent. for Filter No. 221 and 34.5 per cent. for Filter No. 251. During one year Filter No. 251 had a bacterial removal of only 6.5 per cent. The average numbers of bacteria in the effluents from these two filters were practically the same. The minimum numbers in the effluent from Filter No. 221 were 364,000 per cubic centimeter, and in the effluent from Filter No. 251 were 415,000 per cubic centimeter, while the maximum yearly averages for these two filters were 1,131,000 and 943,000 respectively.

Hygienic Efficiency of Principal Filters of Different Types.

Intermittent Filters.

Filter Nos.	Years operated.	Depth (Feet).	Material.	Bacteria per Cubic Centimeter. Average.	Maximum.	Minimum.	Per Cent. Removed. Average.	Maximum.	Minimum.
1, . .	21	5	0.48 sand, .	85,000	99,400	1,900	98.14	99.730	91.34
2, . .	21	5	0.08 sand, .	490	2,100	32	99.97	99.998	99.77
4, . .	21	5	0.04 sand, .	220	800	9	99.88	99.997	99.32
5A, .	8	5	1.40 gravel, .	115,500	214,100	23,000	94.78	98.770	76.80
5B, .	8	5	Cinders, . .	43,700	86,100	19,200	98.00	99.030	96.62
6, . .	21	3⅜	0.35 sand, .	10,900	23,600	520	99.42	99.930	98.72
9A, .	19	5	0.17 sand, .	11,000	31,400	680	99.46	99.900	98.55
10, . .	15	5	0.35 sand, .	4,900	15,600	1,380	99.79	99.980	99.34
14A, .	6	5	0.19 sand, .	2,350	6,940	150	99.86	99.970	99.28
32, . .	3	2½	0.17 sand, .	8,000	15,600	3,600	97.17	98.900	97.35
80, . .	3	4½	Cinders, . .	391,800	1,171,400	86	89.82	99.990	73.30
100, . .	11	5	0.26 sand, .	43,400	88,000	820	94.67	99.880	72.84
116, . .	4	5	0.17 sand, .	1,615	3,800	410	99.82	99.920	96.83
118, . .	3	5	0.23 sand, .	12,050	14,650	10,100	98.88	99.490	97.46
140, . .	2	2	0.11 sand, .	1,520	1,800	1,240	99.93	99.950	99.90
141, . .	1	3	0.11 sand, .	150	150	150	99.99	99.990	99.89
305, . .	3	4½	0.27 sand, .	3,700	7,300	1,700	99.72	99.880	99.48
306, . .	3	4½	0.27 sand, .	3,600	7,700	750	99.48	99.870	98.90
313, . .	3	5	0.25 sand, .	9,700	25,500	800	99.26	99.910	98.44
316, . .	3	10	0.25 sand, .	7,900	23,400	115	99.40	99.990	98.56

Secondary Intermittent Filters.

12A, .	6	5	0.19 sand, .	1,500	2,100	485	99.42	99.830	98.91
224, . .	5	4½	0.27 sand, .	35,900	94,300	1,300	89.35	99.330	82.40
249, . .	5	5	0.41 sand, .	30,100	57,500	6,300	91.07	98.040	47.30
250, . .	5	5	0.41 sand, .	46,300	170,200	5,000	86.30	96.880	67.60

Sprinkling or Trickling Filters.

15B, .	6	5	5.10 gravel, .	242,100	328,900	208,400	90.40	95.570	74.07
16B, .	6	5	5.10 gravel, .	271,500	481,500	153,400	89.22	96.770	72.40
135, . .	9	10½	Broken stone, .	101,100	431,500	26,500	93.77	96.980	71.20
136, . .	9	10½	Broken stone, .	71,500	123,900	41,300	93.67	97.470	79.30
233, . .	5	5	Clinker, . .	305,100	506,400	120,900	78.10	92.570	54.40
235, . .	5	5	Clinker, . .	296,800	982,000	110,100	78.60	93.250	49.20
247, . .	5	5	Broken stone, .	302,600	427,800	148,200	78.10	88.600	67.50
248, . .	5	8	Broken stone, .	217,600	409,000	54,700	84.20	94.420	73.30

Contact Filters.

103, . .	7	5	Coke, . .	158,300	365,200	44,100	82.10	92.200	69.10
175, . .	8	5	Coke, . .	461,500	987,700	131,500	76.40	92.120	11.70
176, . .	8	5	Coke, . .	408,200	631,500	194,600	76.00	87.300	64.70
221, . .	6	3½	Broken stone, .	626,600	1,181,000	364,400	60.60	63.600	38.00
251, . .	5	2½	Coke, . .	616,200	948,000	415,500	34.50	44.800	6.30

Suitability of Effluents from Sewage Filters for Drinking.

In the special report for 1890 the suitability of the effluents from intermittent sand filters for drinking was discussed as follows:—

Although nearly all of the bacteria that were in the sewage did not live to pass through the filters, there have been found in the effluents from filters of coarse sand more bacteria than are found in public drinking supplies, and

some of these evidently come from the sewage; and until we learn that disease-producing bacteria are not among those that come through, we must assume that they may be among them, and, although reduced in numbers to such an extent that they may do no harm, we do not yet know enough to allow us to assume that the very small number of one or two in a thousand of the number in the sewage that come through may not increase in the human body or under other conditions to such numbers as to be harmful. From this cause we are not able to assume that the effluents from the coarse sand filters 5 feet in depth are suitable for drinking. We find, for each of the filters filtering sewage, a well the water of which is used for drinking by many people, but is in fact sewage not so well purified as the effluent from the filter with which it is compared. This is not presented to show that the effluents from the filters are good for drinking, for we have no reason to so regard them, and we should without hesitation pronounce the well waters unsafe to drink; but we present this comparison to show that waters in every way as impure and as certainly derived from sewage as the effluents from the several sewage filters are being used daily, and have been used for years by multitudes of people, without their knowing that they were harmed by them. These comparisons have been made, not to advise drinking any of the well waters that have been cited, nor any of the effluents from the sewage filters, but to show that as people are drinking such waters with impunity, with which the effluents from the filters of fine sand compare favorably in every respect, there can be no doubt that the effluents from such filters can be turned into a drinking-water stream, where they will be much diluted, without risk of injury to those who drink from it. — Special report for 1890, pp. 598-600.

These conclusions, drawn nearly twenty years ago from the results of two or three years' study, have been confirmed by the test of twenty-one years' experience. The object of sewage purification is not to make drinking water out of sewage, but simply to convert it into an inoffensive liquid which may be disposed of by dilution in a convenient stream without causing a nuisance. To make the water from that stream pure enough for drinking, is a separate problem and one distinct from the question of sewage purification. While it is possible to purify sewage by intermittent filtration at a low rate through fine sand, to such an extent that it may at times compare favorably as regards bacterial contents with good drinking waters, experience has shown that it is not possible so to control the purification process that such an effluent may be obtained at all times. The effluents from nearly all of the intermittent filters have contained numbers of bacteria as great or greater than those contained in the water of the Merrimack River and other badly polluted streams, which would never be considered safe sources for water supply without adequate filtration, and the effluents from the contact and trickling filters, containing many times as many bacteria, could not under any circumstances be considered as potable waters.

Biochemistry of Sewage Purification.

The action of any sewage filter is in part mechanical or physical and in part biological or biochemical. Before considering the biochemistry of sewage purification it may be well to state the manner in which it is believed the purification is accomplished within filters of various types. As sewage passes through a sand filter the suspended matters are held back largely through a straining action. In filters of coarse materials, such as trickling and contact filters, this straining action is comparatively slight unless the filters have become clogged. As the filter matures the particles of material become coated with a gelatinous film, consisting of deposited organic matter which in time contains a rich growth of bacteria, algæ, protozoa, rotifers and some higher organisms. As the sewage passes over this gelatinous coating, the suspended matters stick to it and are held back mechanically. The decomposition of the higher forms of albuminous and carbonaceous substances, of which this suspended matter is largely composed is the result in part of bacterial action, but is also brought about in a considerable measure by the higher organisms. The physical power of absorption possessed by the gelatinous coating also plays an important part in the purification process. The soluble organic substances and some of the colloidal matters are absorbed by it, and are thus brought into intimate association with the biological fauna and flora living therein and with the products which they have formed.

The biochemical reactions occurring in the deposited matter and in the sewage while it is in the filter may be divided into three classes, — putrefaction and decay, oxidation and nitrification, and denitrification. The end products of putrefaction and decay are similar, the albuminous matter being first broken down into compounds of less complex structure, such as albumoses and peptones, and these in turn being further decomposed into ammonia, putrefaction being the term applied to the breaking down of organic matter by anaerobic bacteria in the absence of free oxygen, while decay is the term applied to the process when it takes place in the presence of oxygen. In intermittent sand filters and in trickling filters the process of decomposition is largely aerobic, and putrefaction occurs only when the filter has become clogged or when for some other reason insufficient air is present. In a contact filter, however, the filter being filled with sewage which is allowed to stand in contact with the material for some time, the oxygen is frequently exhausted and anaerobic actions may occur. The processes of nitrification and oxidation can occur only in the presence of free oxygen, marking on the one hand the conversion of the ammonia produced by putrefaction or decay to nitrites and nitrates, and on the other the oxidation of carbonaceous products

to carbonates and free carbonic acid. In intermittent sand and trickling filters these processes go on simultaneously and continuously once the filter has become matured. In contact filters the oxidation process can occur only at such times as the filter is filled with air, and becomes dormant when the oxygen of the air has been used up or when the filter is filled with sewage. Denitrification is the term applied to the reduction of the nitrates and nitrites to ammonia and to free nitrogen with the liberation of oxygen.

In the processes of putrefaction and decay, and in denitrification, a certain portion of the nitrogen is liberated as gaseous nitrogen. The oxygen liberated during denitrification is usually absorbed at once by any unsaturated organic compounds which may be present. In addition to these biological processes there may be secondary reactions between the various by-products. In fact, it is generally believed that the lower oxides of nitrogen act as carriers of oxygen, being alternately oxidized and reduced under certain conditions.

If the sewage remains in the filter so long that all the nitrates formed by oxidation are reduced, no nitrates will be found in the effluent. Since most of the unsaturated compounds produced during the anaerobic or putrefactive stage are readily soluble, and would be found dissolved in the effluent from the filter in such a case, unless the effluent were aerated or immediately mixed with water containing a sufficient supply of oxygen, conditions would be favorable for the continuation of the putrefactive processes and a nuisance would be created. In other words, the effluent from the filter would be putrescible. It is conceivable that the oxidation and reduction processes might be so nicely balanced in the filter that all of the available oxygen would be used, including that of the nitrates and nitrites, and that an effluent entirely lacking in nitrates and nitrites might, under these conditions, be entirely stable. It has not been the general experience at Lawrence, however, that a stable effluent can be obtained without the presence of nitrates in the effluent, although such an effluent has occasionally been produced. In other words, in none of the filters operated has that nicely balanced reaction been established except on a few occasions, and considering the marked influence which small variations in the temperature and the strength of the applied sewage may exert on the biochemical reactions, it is not to be wondered at that such a condition can be maintained for a short period of time only.

If partial anaerobic action has already taken place before the sewage goes to the filters, as in the case of septic sewage, the organic matter may be in such a condition that it is not readily acted upon by putrefactive processes, in which case a considerable proportion of it would

be oxidized, if conditions for oxidation were favorable, and a high degree of nitrification and a nonputrescible effluent would result. This would explain the much higher per cent. of nitrates in the effluent from contact Filter No. 103, which received septic sewage, than from similar contact filters which received strained or untreated sewage. On the other hand, the process of putrefaction in preliminary treatment may be carried to such a point that the organic matter will be in a very unstable condition. It will then absorb the oxygen so quickly that the slower process of nitrification cannot become operative within a filter. This point has been discussed elsewhere under the filtration of septic sewage, and the advisability of thoroughly aerating septic sewage before applying it to filters has been noted.

It is to be borne in mind that these various biological reactions do not occur immediately. When a new filter is started, very little change is noted in the chemistry of the sewage which is passed through it during the first few days. The products of decomposition then appear in the effluent, and these are followed later by the products of oxidation and nitrification. In other words, the organic matter must be held back and the micro-organisms must develop within or upon it. They then begin to produce the reactions noted in the effluent. It is extremely probable that the ammonia, nitrates and nitrites found in the effluent at any given time are largely derived from organic matter which has been deposited some time previously, and are not obtained from the sewage applied on the day the sample of effluent was collected. That this is true is evident from the record of storage and decomposition of nitrogen in certain of the filters in which the amount of oxidized nitrogen in the effluents was much greater than the total nitrogen content of the applied sewage during certain periods. This, of course, can only mean that previously stored nitrogenous matter is being worked over and oxidized. Additional evidence that the reactions are slow ones is shown by the results of biochemical studies with pure cultures, discussed further on, in which the production of ammonia, the reduction of nitrates and the oxidation of ammonia to nitrates were found to take place slowly and gradually.

The question of nitrification in filters of different types, and the various conditions effecting nitrification, have been considered elsewhere, and it has been shown that the amount of nitrates given off in the effluents of the aerobic filters, that is, the intermittent sand filters and the trickling filters, is usually much greater than in those from contact filters. The liberation of nitrogen by these various filters has also been discussed elsewhere, and it has been shown that contact filters in which denitrification processes may be active when the filter is filled with

sewage liberate larger quantities of nitrogen than the purely aerobic filters.

The measure of the actual purification of sewage produced by a filter is obtained largely by means of chemical analysis. While it is known that various reactions go on in the filters, and while the end products of these reactions can be measured by means of chemical analysis and the amount of change which has taken place in the filters determined, it has not been possible through lack of proper methods until within a very few years to isolate the various groups of bacteria performing these chemical changes, and to measure their activity. In other words, the ordinary determinations of numbers of bacteria do not yield information concerning the part which bacteria of different types play in the process of purification. Many investigators have attempted, with more or less success, to isolate the various types of bacteria responsible for the different chemical changes in sewage, and to study quantitatively the reactions produced by them. It is with this phase of the subject that the present chapter has to deal.

In 1888–90, inclusive, investigations were made of the phenomena of nitrification, and attempts were made to isolate the organisms causing this reaction. These studies were repeated in 1896–97 and a portion of the earlier results were confirmed, but, owing to an unfortunate accident in the laboratory, were not brought to a satisfactory completion. During 1903–04 extensive studies were made to determine what biochemical reactions occur in different methods of sewage disposal, what types of bacteria are responsible for these reactions, and the relative numbers of bacteria of the various biochemical groups, together with the amount of change which each type of bacteria is able to produce. Attempts were made to isolate from filter sand, from sewage and from the effluents of sewage filters, types of bacteria capable of producing certain results, and to work out by determinations of the number of bacteria of these types present in the samples tested the chief reactions taking place in the sample or filter under examination. These studies were undertaken largely to explain in part the somewhat poor purification results obtained from some of the large out-of-door filters at Lawrence during the winter, and to account for differences in the degree of purification accomplished by some experimental contact filters.

Studies of Nitrification and the Nitrifying Organisms.

Extensive investigations of the biochemistry of nitrification, with attempts to isolate the specific organisms to whose activity these phenomena were attributed, were made co-operatively by Dr. Jordan and Mrs. Ellen H. Richards in the years 1888 to 1890, inclusive, and were published in

the special report for 1890 as a special paper. The results obtained and the difficulties encountered are shown by the following condensed quotations from that report: —

We have considered it of fundamental importance to determine the distribution of the nitrifying organism, and, if possible, to ascertain the relative frequency with which it occurs over a wide area. The question, for instance, naturally arose, is the nitrifying organism present in the Boston city water, since this is the water used in making up our solutions. To this question we are able to give a decided affirmative. Ammoniacal solutions carefully made with tap water always nitrify. Repeated experiments show that the nitrifying organism is invariably present in this water. If the nitrogenous solution be first sterilized and then inoculated with fresh tap water, the same course is followed, with the exception that the period of incubation is considerably lengthened. If seeded with sand from a sewage filter tank, or with garden soil, the whole process is materially quickened, and may even be wholly completed in thirty days. Not only is the nitrifying organism present in Boston tap water, but it appears to be equally common in water from all parts of the State of Massachusetts. So far as our experience has gone, any natural water containing the ordinary amount of free or albuminoid ammonia contains also the nitrifying organism. In these natural waters the nitrifying organism seems to be under wholly normal conditions, and to be abundantly able to effect the oxidation of the small quantities of nitrogen usually present in these waters.

It might, perhaps, be reasonably expected that, since the nitrifying organism is undoubtedly present in all these waters, an examination of gelatin plate cultures of these waters would reveal some particular kind or kinds of colonies common to all, and in that way aid in sifting out the nitrifying organisms. Our experience has shown, however, that such a hope is unfounded. A large number of species of bacteria have been used for inoculation, not only well-known species, like B. prodigiosus, B. megaterium, Proteus, etc., but many species freshly isolated from water, sewage, the sand of nitrifying filter tanks, and similar favorable situations for the nitrifying organism. The experiments have been always prolonged for several months, and in some cases for more than a year. Conditions of temperature, amount of surface exposed to the air, etc., have been varied in many directions. Nitrogenous solutions containing a single species of bacterium have been poured upon sterilized sand, and allowed to settle in such a way as to imitate closely the conditions obtaining in filter tanks. In all, more than one hundred and fifty experiments have been made, covering a period of two years. *In every case, without a single exception, there was not the slightest evidence of nitrification by any single species.* There still remained a plausible explanation of this striking succession of negative results. It might be that, although any one species working alone was not able to effect nitrification, a number of different species working together might be able to produce the desired result. Several experiments were accordingly made with the view of deter-

mining this point. Here again the results were invariably negative. Ammoniacal solutions, inoculated with mixtures of several species, always failed to nitrify.

There was one other possible explanation of our failure to reach consistent positive results by the use of species of bacteria isolated by the method of gelatin plate culture. It might be that the nitrifying organism did not grow on gelatin. We had known for some time that in the filter tanks at Lawrence speedy nitrification was always coincident with a marked decline in the numbers of bacteria. We also observed that, in an ammoniacal solution which is seeded with ordinary pond water containing several species of bacteria, there is during the first few days a rapid multiplication of the contained germs. Nitrification, however, does not, as a rule begin until from ten to fourteen days have elapsed. By the time nitrification begins, the numbers of bacteria have begun to decline, and while the nitrogen in the form of nitrites in the solution is increasing, the numbers of bacteria are steadily diminishing. Accordingly, experiments were begun to attempt to isolate the nitrifying organism by the method of dilution. A flask was first inoculated with a few grains of sand from tank No. 13, and when nitrification was at its height in this solution a small portion was transferred to a second flask, and so on. After a large number of unsuccessful attempts, two solutions were finally obtained which nitrified well, but which gave no growth upon ordinary gelatin plate cultures. Microscopic examinations of these solutions showed them to be inhabited by a particular form of bacillus, and apparently by that alone. These bacilli are short, of a slightly oval shape, and vary from 1.1μ to 1.7μ in length; they are about 0.8μ to 0.9μ broad. They are grouped very characteristically in irregular clumps, and are held together by a jelly-like material. Each aggregation is, indeed, a typical zoöglœa. The aggregations of bacteria were found chiefly on the bottom of the flasks, as was the case with the organism described by Winogradsky. The bacilli stain with some difficulty with the usual aniline dyes. We have not observed independent movement. Owing to the lack of the usual means of diagnosis, it is difficult to determine whether this species is the same as the one described by the Franklands and by Winogradsky. On one important point there appears to be a difference between our results and those reached by the above-mentioned investigators. The organism discovered by them oxidizes ammonia to nitrite, but carries it no farther. Our own flasks give complete oxidation to nitrate. Whether this be due to a difference of conditions, a difference in the virility of the organisms, or a specific difference in the bacteria, we are not at present prepared to say. We are not even prepared to say that there may not have been a mixture of two or more species in our flasks, all agreeing closely in morphological characters, and in giving no growth on gelatin, but differing in important physiological respects. Further investigation is necessary to settle this and other important points regarding the relations of this organism to the process of nitrification. — Special report for 1890, pp. 869–880.

During the years 1896 and 1897 the latter portion of the experiments just described were repeated, and cultures in an active state of nitrification were obtained by the dilution method. Experiments were well under way to isolate the specific organisms from the cultures, and to prove their purity by the use of silica jelly plates, [another contribution of Winogradsky's,] when the cultures were accidentally destroyed. As Winogradsky and others had succeeded isolating the nitrifying organisms in pure cultures by the silica plate method, and had proved that there are two distinct types of such organisms, one oxidizing ammonia to nitrites and the other converting the nitrites to nitrates, and further, as a repetition of the necessary preliminary work would have consumed many months, the investigation was discontinued and attention turned to the study of other problems.

Tendency of the Sand from Filters to induce Denitrification.

During a few winters just previous to 1904, some of the large intermittent filters at the station had yielded effluents, which were bright in appearance and nonputrescible, but were high in free ammonia and low in nitrates. During 1903 and 1904 many experiments were made to determine the causes of these results, and to this end was undertaken the operation of a number of small filters filled with sand from above mentioned intermittent filters as well as others, as described on pages 236 to 240 of the report for 1903. The tendency of the sand from these filters to reduce nitrates was studied, and also the reactions produced by the bacteria in the effluents and materials from different filters. The results of the studies upon bacteria will be taken up further on. To determine the tendency of sand to induce nitrification solutions of potassium nitrate were inoculated with weighed portions of the sands from the various filters, or small filters of these sands were flooded with the nitrate solutions and the amount and character of the nitrogen content was determined from day to day. The results obtained in these various experiments were somewhat contradictory, but, in general, confirmed the opinion that the low nitrates and high free ammonia in the effluents before mentioned were due to a reducing action within the filters, by which any nitrates formed were converted back into ammonia. The following experiment selected from many others will illustrate this.

In this experiment small tubes were filled to a depth of about 6 inches with sand from Filters Nos. 1, 9A and 213. Filters Nos. 1 and 9A had at this time only small amounts of nitrates in their effluents, while the effluent of Filter No. 213 contained a large amount. 200 cubic centimeters of nitrate solution, containing about 9.1 parts of nitrates per 100,000, were then put into each tube, and the outlets opened for a short time in order that the solution might pass into the sand and

that air might be removed. The nitrate solution having passed through was then returned to the tube. These tubes containing the sand and the nitrate in solution were then kept in the laboratory for a number of days. At the same time, water free from ammonia and practically free from nitrates was introduced into control tubes of similar sand. In four days the nitrates in the solution introduced into the tubes containing sand from Filters Nos. 1 and 9A were reduced from 9.1 parts to .92 and .22 part, respectively, while the nitrate solution in the tube containing sand from Filter No. 213 was but slightly reduced. At the same time the nitrites in the liquid in the tubes containing sand from Filters Nos. 1 and 9A increased from practically 0 to 1.6 and .22 parts, respectively, while the nitrite in the solution in the tube containing sand from Filter No. 213 at the end of four days amounted to only .0020 part per 100,000. The free ammonia in the solution in the tubes containing sand from Filters Nos. 1 and 9A increased very rapidly, while that in the tube containing sand from Filter No. 213 increased but slowly, and remained practically constant after twenty-four hours. It was evident, also, that some nitrogen was liberated from the solutions.

This experiment shows that poor nitrification at this time in Filters Nos. 1 and 9A was not caused by cold weather alone, but by groups of bacteria, which tended either to prevent the formation of nitrates or to reduce them when formed.

Relative Distribution of Ammonifying and Denitrifying Bacteria in Sewage and Sewage Effluents.

Some 300 cultures of bacteria common in sewage and in the effluents of sewage filters, carefully selected from the colonies on gelatin plates in such a manner as to represent all of the kinds of bacteria in the sample under analysis, were examined to determine their ability to produce ammonia in pepton solution, to reduce nitrates in nitrated pepton solution and to liquefy organic matter in the form of gelatin. That a considerable percentage of the bacteria commonly found in sewage and in the effluents and material from sewage filters is able to produce ammonia and to reduce nitrates is shown by the results in the following table. — Report for 1904, p. 236.

Distribution of Ammonifying and Denitrifying Bacteria.

Source.	Percentage of Total Bacteria which —	
	Ammonify Pepton.	Reduce Nitrates.
Sewage,	90	70
Septic sewage,	58	59
Effluent, contact filters,	60	61
Effluent, trickling filters,	59	71
Effluent, sand filters,	70	70
Sand from sewage filters,	90	70

Relation between Liquefaction, Ammonification and Denitrification.

Comparing the results obtained with cultures which liquefied the gelatin with those which did not liquefy, it was found that the liquefiers had an average ammonifying power nearly twice as great as the non-liquefiers, and that they had a denitrifying power about three times as great as shown by the total reduction of nitrates, and nearly four times as great as shown by the production of nitrites. In each group of cultures some were found which caused large changes in the nitrogen content and others which caused no change whatever. A study of the individual analyses, however, reveals that while 30 per cent. of the non-liquefying bacteria were unable to reduce nitrates, only 8 per cent. of the liquefying cultures failed in that function. Again, 32 per cent. of the non-liquefying cultures failed to produce nitrites in the nitrate solution, and the same percentage of cultures failed to show any ammonia production in the pepton solution. On the other hand, only 15 per cent. of the liquefying cultures failed to produce nitrites, and the percentage of liquefying cultures which failed to break down pepton into ammonia was only 2 per cent. In other words, the liquefying cultures are much more active in causing putrefaction and denitrification than are the non-liquefying cultures. — Report for 1904, p. 237.

Changes produced by Different Cultures in Solutions containing Nitrogen.

Thirty cultures of bacteria, representing the forms most commonly found in sewage and the effluents from sewage filters, were studied carefully to determine the character and amount of change which they were able to produce in the nitrogenous contents of solutions containing nitrogen in the form of commercial pepton and potassium nitrate, it being assumed that the reactions produced by bacteria under these conditions would be produced by the same kind of bacteria in sewage during the various processes of purification.

From the results obtained it is possible to state definitely that bacteria common in sewage purification are able to produce ammonia from organic matter, to reduce nitrates to nitrites, to ammonia, and probably to elementary nitrogen, to liberate nitrogen from solutions containing organic matter, either with or without the presence of nitrates or its reduction products, and to fix atmospheric nitrogen. Many sewage bacteria also produce the lower oxides of nitrogen as reduction products of nitrates, which oxides play an important part in the further decomposition of the organic matter in solution, either through catalytic action or by direct chemical reaction. Furthermore, certain of these bacteria may produce an oxide or at least a compound of nitrogen intermediate between nitrates and nitrites, which apparently has not been noted hitherto.

The amount of ammonia produced by the different cultures and the rate of ammonification varied considerably, some of the cultures reacting as early

as the fourth day, while other cultures, which eventually reacted strongly, did not begin to ammonify until after periods of ten to fourteen days. Similar phenomena were noted with regard to the reduction of nitrates. Some cultures reduced the nitrates rapidly and completely, some reacted only after a considerable time, and others caused no change. Some cultures were able to reduce the nitrates to nitrites, ammonia and elementary nitrogen continuously from the start, while with other cultures the reduction to these various bodies occurred consecutively, and with still others one or another of the reduction products was not formed during the period over which the examination of the cultures extended. In a few instances nitrites were produced in quantities far greater than the amount of nitrates, and if the results are not in error, this can be explained only on the supposition that a direct oxidation or nitrification occurred.

Eighteen of the 30 cultures lost nitrogen in the pepton solution, and 12 of the cultures showed a gain in nitrogen. In the nitrated solution, 15 of the cultures showed a loss of nitrogen and 13 gained. Eighteen of the cultures agreed as to gain or loss of nitrogen as determined in the two solutions. Two of the cultures showed no change in the nitrate solution, and 10 of the cultures showed a gain or loss of nitrogen in the pepton solution, when the reverse was true in the nitrate solution. With 20 cultures a greater reduction in total nitrogen occurred in the nitrate solution than in the pepton solution, either through increased activity of the bacteria in the presence of nitrates, or, as is more probable, through secondary reactions between the decomposition products of the nitrates and organic nitrogen. Seven of the 24 cultures which showed a reduction of organic nitrogen of 0.5 part or more failed to reduce nitrates, while 3 of the 6 cultures which did not cause any material reduction in the organic nitrogen were able to produce a decided reduction of nitrates. — Report for 1904, pp. 238-240.

Quantitative Expression of Biochemical Functions.

In order to make these biochemical studies of practical value as methods for sewage analysis, it was necessary that they be expressed quantitatively and according to some definite formula. The liability of a change in the character of the sewage by the action of its bacterial contents, or by the action of the bacteria in the filter, depends on the number of bacteria at work and upon the individual power of those bacteria to produce the changes in question, this being called the potential of the sewage under the given conditions. The quantitative expression of the potential is the coefficient, this coefficient being the product of the amount of chemical change which the individual bacteria are able to produce in a definite time by the numbers of bacteria which are producing that reaction. Thus the numerical expression, of the total ability of the bacteria in a sample to produce ammonia from organic matter, is the ammonifying coefficient; of the total ability to reduce nitrates is the denitrifying coefficient, and the total ability to liquefy albuminous matter is the liquefying coefficient. The term 'nitrogen-liberating

coefficient' is the expression of the ability to liberate nitrogen from nitrates, and is independent of the total gain or loss of organic nitrogen previously discussed. For convenience, the amount of change produced in a solution containing 0.1 per cent. of pepton, a solution containing 0.1 per cent. of pepton and potassium nitrate equivalent to 10 parts nitrogen per 100,000, and in Standard gelatin, during seven days' incubation at 20° C., were selected as a standard. Each culture represents an aliquot portion of the total number of bacteria in the sample, and the amount of ammonia produced from organic matter by this culture, expressed as parts of nitrogen per 100,000, is the ammonifying power of the culture. The ammonifying power of the culture multiplied by the number of bacteria of that type in the sample expressed as millions is the ammonifying coefficient of the type, and the sum of the ammonifying coefficients of all the types in a given sample is the ammonifying coefficient for the sample. The denitrifying, nitrogen-liberating and liquefying coefficients are obtained in a similar manner. — Report for 1904, p. 241.

Application of the Biochemical Methods to the Study of Sewage and the Effluents from Sewage Filters.

During the first six months of 1904 a considerable number of sewages and sewage effluents were examined by the new biochemical methods previously described. An inspection of the results of these examinations reveals that there was a considerable variation in the coefficients as determined for the Lawrence sewage at different times, and also that the coefficients for the Andover sewage were much greater than those for the Lawrence sewage. The ammonifying coefficients of the effluents from both septic Tanks A and D-1, in which the sewage at this time was receiving from twenty to twenty-four hours' storage, were also greater than those of the sewages entering the tanks. With the septic sewages D-1, D-2, D-3, D-4 and D-5, which were receiving respectively one, two, three, four and five days' storage, an interesting fact is noticed in that both ammonifying, denitrifying and nitrogen-liberating coefficients were steadily reduced with increased storage. Comparing the effluents of contact Filters Nos. 103, 175 and 176 with the effluents of trickling Filters Nos. 135, 136 and 189, the variation in free ammonia as determined by chemical analysis agrees fairly well with the variation in the ammonifying coefficients. The nitrate-reducing and nitrogen-liberating coefficients of the contact filters, however, are many times greater than those of the trickling filters. Comparing the biochemical and chemical analyses of samples collected during the winter months from Filters Nos. 1 to 10, inclusive, in nearly every case high ammonifying coefficients are found to be accompanied by high free ammonia and high denitrifying coefficients, correlated with considerable free ammonia and nitrites and low nitrates. A somewhat different condition is to be noted in samples from these filters during the summer months. The high ammonifying, nitrogen reducing and liberating powers which all the filters except Nos. 2 and 10 had exhibited during the cold weather were lacking when nitrification had again become active. On

the other hand, Filters Nos. 4 and 10, which continued to nitrify actively during the winter, did not show any ammonifying, denitrifying or nitrogen-liberating powers either winter or summer. These results are further confirmation that during exceptionally cold weather the nitrifying bacteria are more or less inactive, and that much of the change going on in a filter is accomplished by bacteria of other types, which are apparently capable of performing their work at low temperatures. — Report for 1904, p. 242.

The results of the various chemical and biochemical examinations are tabulated on pages 243 and 244 of the report for 1904.

Conclusions.

To summarize the results of the biochemical studies — the amount of purification which a sewage will undergo in a given time depends on the number of bacteria at work and on the power of the individual bacteria to perform that work, the process of purification being accomplished by the bacteria present in the sewage working together with the bacteria which have found lodgment in the filtering material. The chemical changes which affect the nitrogen in the sewage in the process of purification are (1) putrefaction, (2) nitrification and oxidation, (3) denitrification, (4) nitrogen liberation, and (5) fixation of atmospheric nitrogen.

Of these reactions, putrefaction and nitrification are beneficial. It is a question whether denitrification should be encouraged or not. It depends upon whether the liberation of nitrogen incidental to this process outweighs the effect of the decrease in active nitrification. Nitrogen liberation is desirable provided that it takes place in such a manner as to leave the effluent of a filter in a stable and highly oxidized condition, while the fixation of atmospheric nitrogen in a sewage filter is to be avoided if possible. All these processes go on probably to a greater or less extent in sewage filters of the various types. If a filter is so constructed and operated that oxidizing processes are active throughout the entire depth, the reduction of nitrates is largely prevented, and a large proportion of the nitrogen in the applied sewage will appear in the effluent as nitrates. If, however, the construction and operation of the filter is such that both oxidizing and reducing actions occur, or that the reducing action predominates, much nitrogen will be liberated. The effluents of trickling filters in good operation contain much of the nitrogen applied, while the effluents of contact filters in good operation show a large disappearance of nitrogen, and this is shown not only by computations of the amount of nitrogen applied and appearing in the effluent of such filters as determined by chemical analyses, but also by the results of the biochemical examination of the effluents from the vari-

ous classes of filters. The effluents of intermittent sand filters in good operation also contain considerable portions of the applied nitrogen. During the cold weather, however, nitrification may become inert in filters of this type, and while the effluents may remain of good appearance, high free ammonia and low nitrates will prevail, combined with a considerable loss of nitrogen.

It was the intention when this review was begun to include a summary of the work at Lawrence on manufacturing wastes. Owing, however, to the length which the review as presented has reached, this must be postponed for the present, but will appear in a subsequent report of the Board.

In this review certain mistakes occurring in previous reports have been rectified. On this account a few statements and figures will be found to differ from those previously published.

WATER FILTRATION.

During 1908 studies on the filtration of polluted water by slow sand filters, by double filtration and by slow sand and mechanical filters with the aid of coagulants have been continued and many valuable data have been obtained. In addition, a systematic study on the relative efficiency of filters of the same depth and of the same effective size of sand, but operated at different rates, has been carried on. Owing to the space occupied by the preceding chapter on sewage disposal, however, the results of these studies are omitted here, but a complete discussion will be given in a subsequent report.

Data in regard to the filters which purify the water supply of the city of Lawrence are given below.

Lawrence City Filters.

During 1906 and 1907 a new covered water filter was constructed to supplement the supply of filtered water from the large uncovered filter, 2½ acres in area, which has been in use since September, 1893. The new filter is ¾ of an acre in area, and contains 4½ feet in depth of sand of an effective size of about 0.25 millimeter. It was put into operation Nov. 4, 1907, at a rate of 1,000,000 gallons per acre daily. The filtered water was wasted until Jan. 4, 1908. Since that date, however, it has been supplied to the city. The rate of operation was gradually increased during January and February, 1908, until a rate of 3,000,000 gallons per acre daily was obtained; and at this rate the filter is now operated. The effluents from both the old and the new filter flow into the same pump-well, from which the filtered water is pumped to the distributing reservoir.

In the following tables are shown the average chemical and bacterial analyses of the Merrimack River water as it flows to the filter; of the effluents from both the old and new filters; of the mixed effluents as pumped into the distributing reservoir; of the water after passing through the reservoir and after passing through the distribution system of the city to faucets at City Hall and at the experiment station.

Average Chemical Analyses.

Merrimack River. — Intake of the Lawrence City Filter.

[Parts per 100,000.]

Temperature (Deg. F.).	Appearance.		Ammonia.			Chlorine.	Nitrogen as —		Oxygen Consumed.	Iron.	Hardness.
	Turbidity.	Color.	Free.	Albuminoid. Total.	Albuminoid. In Solution.		Nitrates.	Nitrites.			
53	0.2	.40	.0142	.0200	.0167	.398	.012	.0004	.53	.0640	1.0
Effluent of the Lawrence City Filter (Old Filter).											
54	0.1	.31	.0096	.0094	-	.425	.028	.0008	.36	.0912	1.4
Effluent of the Lawrence City Filter (New Filter).											
54	0.1	.31	.0061	.0101	-	.415	.023	.0007	.37	.0520	1.6
Water from the Outlet of the Distributing Reservoir.											
54	0.1	.33	.0051	.0084	-	.419	.037	.0002	.34	.0714	1.4
Water from a Tap at Lawrence City Hall.											
54	0.1	.34	.0084	.0081	-	.420	.066	.0001	.30	-	1.3
Water from a Tap at the Lawrence Experiment Station.											
55	0.1	.33	.0027	.0075	-	.412	.036	.0001	.31	-	1.4

Average Bacterial Analyses.

Merrimack River. — Intake of the Lawrence City Filter.

Bacteria per Cubic Centimeter. 20° C.	Bacteria per Cubic Centimeter. 40° C. Total.	Bacteria per Cubic Centimeter. 40° C. Red.	Per Cent. of Bacteria removed. 20° C.	Per Cent. of Bacteria removed. 40° C. Total.	Per Cent. of Bacteria removed. 40° C. Red.	Per Cent. of Samples containing B. Coli. 1 c. c.	Per Cent. of Samples containing B. Coli. 100 c. c.
6,500	100	62	-	-	-	100.0	100.0
Effluent of the Lawrence City Filter (Old Filter).							
90	23	17	98.6	77.0	72.6	17.4	63.0

Average Bacterial Analyses — Concluded.

Effluent of the Lawrence City Filter (New Filter).

Bacteria per Cubic Centimeter.			Per Cent. of Bacteria removed.			Per Cent. of Samples containing B. Coli.	
20° C.	40° C.		20° C.	40° C.			
	Total.	Red.		Total.	Red.	1 c. c.	100 c. c.
120	10	4	98.2	90.0	93.5	30.8	79.9
Mixed Effluents as Pumped to Distributing Reservoir.							
130	47	41	-	-	-	18.6	66.0
Water from the Outlet of the Distributing Reservoir.							
48	11	7	-	-	-	12.1	65.1
Water from a Tap at Lawrence City Hall.							
38	5	2	-	-	-	5.0	58.5
Water from a Tap at the Lawrence Experiment Station.							
39	5	2	-	-	-	7.6	59.6

Average Chemical Analyses.

Merrimack River. — Intake of the Lawrence City Filter.

[Parts per 100,000.]

Temperature (Deg. F.).	Appearance.		Ammonia.			Chlorine.	Nitrogen as —		Oxygen Consumed.	Iron.	Hardness.
				Albuminoid.							
	Turbidity.	Color.	Free.	Total.	In Solution.		Nitrates.	Nitrites.			
53	0.2	.40	.0142	.0200	.0167	.398	.012	.0004	.53	.0640	1.0

Effluent of the Lawrence City Filter (Old Filter).

54	0.1	.31	.0096	.0094	-	.425	.028	.0003	.36	.0912	1.4

Effluent of the Lawrence City Filter (New Filter).

54	0.1	.31	.0061	.0101	-	.415	.023	.0007	.37	.0520	1.6

Water from the Outlet of the Distributing Reservoir.

54	0.1	.33	.0051	.0084	-	.419	.037	.0002	.34	.0714	1.4

Water from a Tap at Lawrence City Hall.

54	0.1	.34	.0084	.0081	-	.420	.036	.0001	.30	-	1.3

Water from a Tap at the Lawrence Experiment Station.

55	0.1	.33	.0027	.0075	-	.412	.036	.0001	.31	-	1.4

Average Bacterial Analyses.

Merrimack River. — Intake of the Lawrence City Filter.

Bacteria per Cubic Centimeter.			Per Cent. of Bacteria removed.			Per Cent. of Samples containing B. Coli.	
20° C.	40° C.		20° C.	40° C.			
	Total.	Red.		Total.	Red.	1 c. c.	100 c. c.
6,500	100	62	-	-	-	100.0	100.0

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Average Bacterial Analyses — Concluded.

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48	11	7	-	-	-	12.1	65.1
Water from a Tap at Lawrence City Hall.							
38	5	2	-	-	-	5.0	58.5
Water from a Tap at the Lawrence Experiment Station.							
39	5	2	-	-	-	7.6	59.6

Average Chemical Analyses.

Merrimack River. — Intake of the Lawrence City Filter.

[Parts per 100,000.]

Temperature (Deg. F.).	Appearance.		Ammonia.			Chlorine.	Nitrogen as —		Oxygen Consumed.	Iron.	Hardness.
	Turbidity.	Color.	Free.	Albuminoid. Total.	Albuminoid. In Solution.		Nitrates.	Nitrites.			
53	0.2	.40	.0142	.0200	.0167	.398	.012	.0004	.53	.0640	1.0
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54	0.1	.33	.0051	.0084	-	.419	.037	.0002	.34	.0714	1.4
Water from a Tap at Lawrence City Hall.											
54	0.1	.34	.0034	.0081	-	.420	.036	.0001	.30	-	1.3
Water from a Tap at the Lawrence Experiment Station.											
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20° C.	40° C. Total.	40° C. Red.	20° C.	40° C. Total.	40° C. Red.	1 c. c.	100 c. c.
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39	5	2	-	-	-	7.6	59.6

EXAMINATION OF RIVERS.

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During the year 1908 the examination of rivers has been carried on in connection with the examination of sewer outlets and the effect of sewage disposal. The year has been the driest for twenty-five years, and the flow of streams has consequently been much lower than the average. The quantity of polluting manufacturing wastes discharged into the streams has probably been less than usual, on account of the financial depression; nevertheless, the effect of the pollution of streams has in general been more marked than in previous years.

The sources of pollution of most of the various streams and tidal waters have been examined, the sewer outlets and points of discharge of manufacturing waste and refuse have been inspected, and samples of water have been collected for analysis at frequent intervals at various points on the more important rivers. A brief summary of the results of these investigations follows.

The more important rivers examined have been the following: —

Assabet, Blackstone, Charles, Chicopee, Concord, Connecticut, French, Hoosick, Housatonic, Merrimack, Millers, Nashua, Neponset, Quaboag, Sudbury, Taunton, Ten Mile, Ware and Westfield.

Blackstone River.

The Blackstone River, notorious among the polluted rivers of the State, has long been a nuisance to the inhabitants of the valley on account of its pollution by the sewage of the city of Worcester, and in 1886 an act was passed by the Legislature directing the city to purify its sewage. The sewerage system of the city of Worcester, originally constructed on the combined plan, has in recent years been largely modified, with a view to separating the storm water from the sewage and reducing the quantity of sewage to be treated. The precipitation works, begun in 1890, were subsequently enlarged sufficiently to provide for the treatment of the dry-weather flow of sewage, and in recent years filter beds have been constructed from time to time for the purification of the sewage by intermittent filtration. At the end of 1908 the total area of filter beds amounted to about 60 acres,[1] and the total quantity of sewage applied to them averaged about 25[1] per cent. of the entire quan-

[1] Report of superintendent of sewers of the city of Worcester.

tity delivered at the sewage-disposal works. The condition of the Blackstone River below the city of Worcester in 1908, judging from the results of examinations, has changed but little from previous years.

In the village of Cherry Valley on Kettle Brook, one of the headwaters of the river, there is a considerable number of factories and mills, including several woolen mills, from which such quantities of foul refuse are discharged as to pollute the stream greatly and make it a nuisance in this part of its course. Kettle Brook, after leaving the Cherry Valley district, flows through a number of large ponds, in which the effect of the pollution is greatly diminished by sedimentation, dilution, etc., and when it reaches the city of Worcester its condition is greatly improved.

The Mill River, one of the tributaries of the Blackstone, formerly seriously polluted by the sewage of Hopedale, has been in much better condition than formerly since the removal of the sewage from the river, though it still receives considerable liquid waste, containing iron, which forms an unsightly rusty precipitate on the bottom of the stream for a considerable distance below the town of Hopedale.

Charles River.

The Charles River is badly polluted below Milford by sewage discharged from that town, and its condition was very offensive during much of the year 1908. A relief for the offensive condition of this stream will soon be provided by the construction of the Milford sewage-disposal system, already nearing completion.

One of the tributaries of the Charles River flowing from Franklin is badly polluted by manufacturing wastes, but the effect of these pollutions disappear lower down, and the main stream shows little evidence of pollution as it flows through the extensive areas of lowland between Dover and Newton. It receives some additional pollution by the discharge of wastes from factories and mills in Newton, Waltham and Watertown, but, with a few exceptions, these pollutions are unimportant. Sewers are available for the disposal of the sewage and most of the offensive manufacturing wastes throughout the lower portion of the course of the stream, and recent legislation provides a method which can be employed to prevent serious pollution.

Charles River Basin.

Until the year 1908 the Charles River has been a tidal stream in which salt water has ebbed and flowed as far as the lower dam at Watertown, about 8 miles from its mouth. The construction of a dam at Craigie Bridge near its mouth, authorized in 1903, was nearly com-

pleted in 1908, and on October 20 in that year a temporary shut-off dam was closed and tide water excluded.

In connection with the plan of maintaining this basin hereafter as a fresh-water park, the work of separating the sewage from storm water in the districts of Boston and Cambridge, drained by this portion of the river, which hitherto have been served by a combined system of sewers, has recently been begun. The dry-weather flow of sewage in these areas is removed to the main sewer outlets in the harbor, but at times of rain considerable quantities of sewage still discharge into the basin through storm overflows whenever the quantity flowing in the sewers is increased by rain or melting snow to a point beyond the capacity of the intercepting system. The pollution of this portion of the Charles River by sewage cannot be prevented until complete separation has been effected, but the amount of pollution entering the basin should gradually decrease if the separation of the sewage from the storm water is continued.

Chicopee River.

The Chicopee River is formed by the confluence of the Ware, Swift and Quaboag rivers in the town of Palmer. Below that point it receives the sewage of Ludlow, and near its mouth a large portion of the sewage of Chicopee. The pollution of the river at the present time is not serious, though a local nuisance is created at Chicopee Falls, where one of the sewer outlets is unfavorably located at the river bank, and a more serious nuisance near the mouth of the river, where the main outlet of the city discharges at the south side of the stream in such a manner that the river bank is badly polluted and a nuisance created in the neighborhood. This outlet is being extended to a point of discharge farther out in the Connecticut River.

Of the tributaries of the stream the Swift River receives comparatively little pollution by sewage, and the effect of the manufacturing waste by which it is polluted has not been seriously noticeable during the past year.

The Quaboag River is polluted by the sewage of the town of Palmer at a point not far from its mouth. The evidences of pollution are very marked for a considerable distance from the sewer outlets, but the objectionable conditions disappear farther down, after the sewage has become thoroughly mingled with the water of the stream. The conditions here could be greatly improved if the outlets were properly constructed, so as to discharge the sewage into the current of the stream, where it would be quickly carried away instead of remaining upon the banks, where it collects in dry weather and putrefies.

The upper waters of the Seven Mile River, a tributary of the Quaboag, in Spencer, are polluted by manufacturing wastes, and sewage is also discharged at times from the Spencer sewers directly into the river. The pollution of the streams in this region is unnecessary, since the sewage-disposal area of the town of Spencer is ample for the purification of all of the sewage at all times, and probably most of the manufacturing wastes also, though these should not be admitted to the sewers unless first so treated as to prevent danger of their interference with the operation of the system.

Chicopee Brook, so called, another tributary of the Quaboag River, flowing through the town of Monson, is considerably polluted by sewage and manufacturing wastes in that town. Plans for a sewerage and sewage-disposal system for this town have been prepared during the year.

Of all the streams in the Chicopee River watershed the most seriously polluted is the Ware River, which receives large quantities of manufacturing waste at Barre, Wheelwright, Gilbertville and Ware, and in addition large quantities of sewage, including all of the sewage of the town of Ware, which had in 1905 a population of 8,594. The pollution of the stream at Barre is caused by wool-scouring wastes, which contain great quantities of dirt and grease, and have a very unfavorable effect on the stream for a long distance below the works. At Wheelwright the stream is polluted by paper-mill wastes, and at Gilbertville by wastes from a large woolen mill. Woolen-mill wastes are also discharged into the stream in the town of Ware. The sewage of Ware enters the river at two outlets below the town, and the quantity has become so great in proportion to the flow in the stream that it noticeably affects the river for a long distance below the sewer outlets. It is evident that the time is not far distant when the purification of the sewage of the town of Ware, and the removal of much of the objectionable manufacturing wastes from the river, will become necessary to prevent a nuisance. Below the town a serious nuisance already exists, and the stream is badly polluted below the wool-combing works at Barre.

Concord River.

The Concord River is formed by the confluence of the Assabet and Sudbury rivers in the town of Concord. Below this point it receives but little pollution until it reaches North Billerica, where the wastes from woolen mills are discharged into the river. The sewage of the village is purified by intermittent filtration. Near the mouth of the stream in the city of Lowell it is polluted by considerable quantities of foul manufacturing wastes, discharged from various mills, and by one of the principal sewers of the city of Lowell. A considerable relief from the objectionable conditions existing in this stream was obtained some

time ago by the extension of the sewer into the stream, and the construction of a wall along the river bank. The discharge of manufacturing wastes, especially tannery refuse, in a shallow part of the river near this outlet is very objectionable.

The Sudbury River is badly polluted by wastes from the Saxonville mills in Framingham, consisting of waste water from the processes of scouring wool and the washing and dyeing of cloth. The visible effects of this pollution disappear a few miles below the village.

The Assabet River has been the cause of a great amount of complaint during the past year on account of its gross pollution in Westborough, Northborough and Hudson. In Westborough and Northborough its pollution has been caused by the inefficiency of the filter beds of the town of Westborough, due partly to neglect and partly to the discharge into the sewers of wastes from a yeast factory, which interferes greatly with the purification of the sewage.

At Hudson the filter beds have also become inefficient, largely on account of the discharge into the sewers of a quantity of wool-scouring waste, containing enormous amounts of fats, which have clogged the filter beds and interfered with their operation.

At Maynard a nuisance is caused by the discharge of great quantities of manufacturing wastes from a large woolen mill.

Connecticut River.

The Connecticut River is polluted directly by the sewage of a large number of cities and towns, including Montague, Hatfield, South Hadley, Holyoke, Chicopee, Springfield and West Springfield, and receives also the sewage of Northampton and Easthampton, which is discharged into small tributaries close to the main stream. Above Northampton, except for a few local nuisances in the immediate neighborhood of the sewer outlets at Turners Falls, the evidences of pollution are slight, and but little increase is noticeable down to the Holyoke dam, though the banks of the river are badly fouled near Mt. Tom by the discharge of sewage from Northampton and Easthampton, through the Mill and Manhan rivers, into the main stream, at a point where the river receives, in addition to the sewage, a large quantity of waste from a sulphite pulp mill.

Below Holyoke the effect of the pollution by manufacturing wastes is noticeable for a considerable distance in periods of low flow, and there is a rapid increase in pollution as the river passes Springfield and receives a large additional quantity of sewage from that city and neighboring places. The flow of the stream is so great, however, in proportion to the quantity of sewage discharged that the visible effect is slight, though the increasing pollution is shown clearly by chemical analysis of the water.

While the Connecticut River as a whole shows as yet no very serious effect of the pollution which it receives, there are at several places local nuisances caused by sewer outlets along its banks, so placed that the sewage collects near the shore, fouling the river bank and in places greatly polluting the water for considerable distances. In some cases the dry-weather flow of sewage has been carried through a submerged pipe to an outlet 200 feet or more from the bank, and objectionable conditions prevented. The serious nuisance formerly caused by the discharge of a sewer from Holyoke at a point close to the Holyoke dam has recently been removed, and the sewage diverted to an outlet below the city.

The condition of some of the smaller tributaries of the stream is also in some cases very objectionable. The most seriously polluted of these smaller streams is the Mill River in the city of Northampton, where the sewage has been discharged into the stream at various points, chiefly near the lower end of the city. The main sewer outlet discharges into the river at a point about a mile from its confluence with the Connecticut River, and below the outlet the stream, which is very crooked throughout this portion of its course, has hitherto been badly polluted and much obstructed by fallen trees and rubbish of various kinds. Suspended matters from the sewage collecting upon these obstructions, and in eddies and shallow places, have increased the nuisance. Improvements in the sewerage system are now being made, upon the completion of which it is expected that the serious pollution of the stream will be prevented throughout the portion of the city above the main sewer outlet. Below this outlet the channel of the river has recently been cleaned.

The Manhan River has been very badly polluted during the past year by the discharge of sewage from the town of Easthampton, which enters the stream at a point about 3 miles from the Connecticut River. Works for purifying the Easthampton sewage are now under construction.

The sewage of Amherst is discharged into Fort River, one of the tributaries of the Connecticut River, where the conditions are becoming seriously objectionable.

Deerfield River.

The Deerfield River flows through a very sparsely populated region, and receives but little pollution throughout its course. It receives a small amount of direct sewage pollution in Shelburne Falls, and the sewage of the town of Greenfield reaches it through the Green River, a tributary of the Deerfield, which joins it near the mouth. Of the tributaries of the Deerfield, the Green River is the only one which receives any considerable amount of sewage pollution. The condition of this stream has been very offensive in the past year, and the nuisance which it has caused has been the source of much complaint.

French River.

This stream is seriously polluted by manufacturing wastes at several points in its course, and below Webster, as it leaves the State, its appearance in the drier portion of the year is filthy and its odor objectionable. The chief causes of the pollution of the river are the sewage and manufacturing wastes discharged into the stream in the town of Webster.

The French River is also seriously polluted at Rochdale, North Oxford and Oxford by wastes from woolen mills.

Hoosick River.

The Hoosick River is polluted by the sewage of Adams, North Adams and Williamstown, besides large quantities of manufacturing wastes, and is filthy and offensive in appearance and odor in the portion of its course between North Adams and the point where it leaves the State. The south branch of the stream is badly polluted by sewage and manufacturing wastes in Adams, and the condition of both the south and north branches in North Adams is very objectionable. The removal of pollution from this stream has become essential for the protection of the public health.

Housatonic River.

The city of Pittsfield and the towns of Lenox and Stockbridge, in the valley of the Housatonic River, maintain purification works for the treatment of their sewage before its discharge into the stream. The towns of Dalton, Lee and Great Barrington discharge their sewage directly into the river, without treatment. The purification works at Pittsfield care for the greater portion of the sewage of the city, though a portion of it is still allowed to reach the stream through one or two sewer outlets, including an overflow at the pumping station. At Lenox the greater portion of the sewage is discharged into the river at all times. At Stockbridge all of the sewage is treated, and a well-purified effluent discharged into the river.

The river is also polluted — especially in Pittsfield, Dalton and Hinsdale — by manufacturing waste, and is offensive to sight and smell for a considerable distance below Hinsdale and objectionably polluted below Dalton. The west branch of the river is very badly polluted in the city of Pittsfield by manufacturing waste, and is offensive in appearance and odor throughout most of its course in the city. Wastes from a woolen mill, also in Pittsfield, pollute badly the southwest branch of the river, making the stream unsightly and offensive for a considerable distance below the mill.

Merrimack River.

The Merrimack River, the pollution of which has become so great as to be the cause of serious complaint from inhabitants in the lower part of its valley, has been the subject of a special examination during the past year, the results of which have been presented in a special report.

Millers River.

Millers River throughout much of its course is in appearance clean and unobjectionable. Near its headwaters it is badly polluted by the sewage of Winchendon, but the effect of the pollution disappears in the course of its flow through the sparsely settled regions through which it passes for many miles below that town. At Athol it is again polluted by the sewage of the town, and some of the sewer outlets are objectionable, but the effect gradually disappears in the long mill-pond below, formed by the dam at Orange. The sewage of Orange is discharged into the river below the dam, and, except for the nuisances caused by the location of the sewer outlets close to the banks of the river, the condition of the main body of the stream is not objectionable. Near its mouth it receives the sewage of the village of Millers Falls, which has but little effect on the stream.

One of its main tributaries, known as the Otter River, has been considerably polluted at times during the year by the discharge of sewage and imperfectly purified effluent from the sewage-disposal works of the town of Gardner.

Nashua River.

The north branch of the Nashua River is grossly polluted by sewage and manufacturing wastes discharged into the stream in the city of Fitchburg and town of Leominster, and it is filthy and offensive, both in appearance and odor, for a distance of many miles below the latter town. The objectionable condition of this stream was reported to the Legislature in January, 1908 (Senate Document, No. 251, page 10; see also page 33 of this report), but no action has been taken as yet to provide an efficient remedy.

Neponset River.

The Neponset River, which has become a great nuisance on account of its pollution by sewage and manufacturing wastes, has been the subject of legislation, with a view to improving its condition. During the year 1908 nearly all of the sewage formerly discharged into the stream was removed, except in the town of Norwood, where the construction of works

for the purification of the sewage has been begun and will soon be completed. Considerable progress has been made in the prevention of the pollution of the river by manufacturing wastes by changes and economies introduced by the manufacturers in their processes, and in a few cases the construction of purification works for the treatment of the remaining wastes has been begun. The pollution of the river during the past year has doubtless been reduced somewhat by the curtailment of manufacturing, due to the financial depression.

Taunton River.

The most serious pollution of the Taunton River is caused by the sewage of the city of Taunton, which is discharged into the river at the lower end of the city under a plan approved by this Board, which provides for the removal of the sewage from the river before July 1, 1910, and its purification upon lands already secured for the purpose in the town of Berkley.

Among the tributaries of the river, the most unsatisfactory conditions are found in the Nemasket River, which is badly polluted by the sewage of the town of Middleborough. One of the sewer outlets of this town discharges into a ditch several hundred feet from the river, through which it flows with a sluggish current, making a very offensive nuisance in the drier portion of the year. Another main outlet, discharging into a raceway in which there is little or no flow of water during much of the time, creates a serious local nuisance, beside polluting the river.

The Matfield River is polluted by considerable quantities of manufacturing wastes discharged into the stream in the city of Brockton, and tributaries of the river in Bridgewater, Mansfield and Foxborough are considerably polluted by sewage discharged into them in those towns.

Ten Mile River.

The Ten Mile River is very badly polluted by the sewage of Attleborough and by manufacturing wastes discharged into the stream both at Attleborough and at North Attleborough and Plainville farther up stream. The condition of the river is objectionable below North Attleborough and is much worse below the sewer outlets at Attleborough, where it has become a serious nuisance. The necessity of preventing further serious pollution of this stream is evidently recognized by the towns of Attleborough and North Attleborough, which are making preparations to begin the construction of systems of sewerage and sewage disposal.

Westfield River.

The Westfield River drains for the most part a sparsely settled region. Its chief pollution is caused by the sewage of Westfield, which is discharged into the river at two outlets below the town and a short distance above its confluence with the Westfield Little River. The effect of the sewage upon the stream is becoming more and more noticeable about and below the outlets in dry weather.

Near its mouth the river receives sewage from West Springfield and Agawam, but the quantity is small and has but little effect upon the stream. The sewer outlets are, however, in some cases, badly located, and the conditions about them are objectionable.

Sewer Outlets into the Sea and Tidal Estuaries.

Many of the outlets through which sewage is discharged into the sea and tidal estuaries along the coast have been the subject of careful examination during the past year. Chief among these are the great outlets of the metropolitan sewerage systems and the city of Boston, the condition of which has been described in a separate report to the Legislature of 1908.

The most noteworthy change in the condition of the other sewer outlets into tidal waters is the completion of the main trunk sewer and outlet for the sewage of the city of Salem and the town of Peabody. This sewer extends from the neighborhood of Peabody Square through the valley of the North River, and crosses the central part of the city of Salem to a pumping station at Salem Neck, on the westerly shore of Cat Cove, whence the sewage is pumped to an outlet into Salem harbor near Great Haste Island. The completion of these works makes it practicable to provide an outlet for the sewage and the manufacturing wastes which have hitherto made the North River in Salem and Peabody one of the most notorious nuisances in the State.

A general system of sewerage has also been constructed in the town of Peabody, and intercepting sewers are being rapidly extended to intercept and remove the sewage now discharged into the waters about the city of Salem to the new outlet in the harbor.

The effect of the discharge of sewage from the main outlet of the city of Beverly, which discharges into Beverly harbor near Andrews Court, has become much more marked than formerly, and the question of a more satisfactory place of disposal for this sewage is now being taken up.

The sewer outlets of Revere, which formerly discharged into local waters about the town, have now all been abolished, and the sewage is discharged into the metropolitan system.

The sewage of the town of Swampscott is discharged into the sea off Dread Ledge, where the sewage disappears so quickly that little trace of it can be found, even in the immediate neighborhood of the outlet.

Of the outlets discharging into the sea, the most objectionable at the present time are those of the cities of Lynn and New Bedford, where serious nuisances are caused by the discharge of sewage upon flats exposed at low water.

The sewage of the city of Lynn is discharged at the end of a long wharf into a small channel at all stages of the tide, and, as there is no strong current capable of removing it quickly from the shores, the movements of the sewage are influenced largely by the winds, and much of it is carried upon the extensive areas of flats which border the shore in this region, which are covered with deep deposits of sewage sludge. The odor from the flats and shores all about this section of the harbor is offensive and the conditions very objectionable.

At New Bedford about two-thirds of the sewage of the city is discharged at numerous outlets into New Bedford harbor and the Acushnet River in front of the city, while the remaining third is discharged at the head of Clark's Cove, at the extreme southerly end of the city.

Most of the sewers along the harbor and river front discharge into docks or at the ends of wharves, where there is little or no current to remove the sewage, and in consequence deposits of sludge are formed about many of the outlets, creating, in connection with the sewage, many very serious nuisances.

The sewer outlets at Clark's Cove are located, for the most part, near the shore at high water, and at times of low tide the sewage flows in streams across the beach to the water. Clark's Cove is an arm of the sea, having a very limited drainage area, and there are no strong currents capable of removing the sewage. The cove, moreover, opens toward the south, so that the prevailing winds in summer have a tendency to carry the sewage toward the shore. In consequence of these conditions the water all about the shore at the northerly end of the cove is very badly polluted at all times, and large quantities of sludge have been deposited in the shallow water as well as upon the beach between high and low tide. The region about the upper end of the cove is densely populated and its shores are used as a playground by large numbers of children. The conditions here are very objectionable and no doubt injurious to health.

FOOD AND DRUG INSPECTION.

FOOD AND DRUG INSPECTION.

By the Acts of 1908, chapter 238, certain laws relative to the sale of food and drugs, viz., sections 25 and 26 of chapter 75 of the Revised Laws, were repealed. These were the original laws relative to adulterated foods and drugs, antedating by many years the comprehensive act (chapter 263) passed in 1882. Containing the words "knowingly" and "fraudulently," they were impossible of enforcement; providing different penalties, they were in conflict with section 24, which establishes the penalty for violations of sections 16 to 27, inclusive; and, producing nothing but confusion, their repeal was most desirable.

At the close of the period covered by this report the force engaged in the food and drug work of the Board comprised the following persons:—

Hermann C. Lythgoe,	*Chief Analyst.*
Charles H. Hickey,	*First Assistant Analyst.*
Lewis I. Nurenberg,	*Second Assistant Analyst.*
Clarence E. Marsh,	*Third Assistant Analyst.*
Horace F. Davis,	*Inspector.*
Daniel E. McCarthy,	*Inspector.*
Frederick L. Marion,	*Inspector.*
Maurice P. Crowe,	*Inspector.*

The report of the chief analyst presents in detail the work of this department for the year ended Nov. 30, 1908.

The number of samples examined during this period is shown in the following table, together with a summary of the work done since the passage of the law in 1882: —

Food and Drug Inspection (1882–1908).

Summary.	Years. 1908.	Years. Total 1882–1908.
Number of samples of milk examined,	3,934	100,997
Number of samples above standard,	2,764	64,514
Number of samples below standard,	1,170	36,483
Number of samples of other kinds of food examined (not milk),	1,367	62,704
Number of samples of good quality,	1,117	51,166
Number of samples adulterated, as defined by the statutes,	250	11,538
Number of samples of drugs examined,	1,308	19,582
Number of samples of good quality,	990	12,632
Number of samples adulterated, as defined by the statutes,	318	6,950
Total examination of food and drugs,	6,609	183,283
Total samples of good quality,	4,871	128,312
Total samples not conforming to the statutes,	1,738	54,971

Section 7 of chapter 75 of the Revised Laws provides that the State Board of Health "shall annually report to the general court the number of prosecutions made under the provisions of sections sixteen to twenty-seven, inclusive, and an itemized account of the money expended in carrying out the provisions thereof;" and in accordance with this provision the following report is made.

Section 6 of chapter 386 of the Acts of 1906, "An Act relative to the labeling of certain patent or proprietary drugs and foods," provides, furthermore, that it "shall be the duty of the state board of health to cause the prosecution of all persons violating the provisions of this act;" and inasmuch as this duty is performed by the food and drug department of the Board, and under the annual appropriation therefor, no special appropriation having been provided, the prosecutions made under the provisions of this act are included.

The total number of prosecutions entered during the fiscal year ended Nov. 30, 1908, was 433, of which 373 were made under the provisions of sections 16 to 27, inclusive, of chapter 75 of the Revised Laws, and 60 under those of chapter 386 of the Acts of 1906. Of the latter, 9 were for the sale of cocaine without prescription, and 51 were for the sale, without prescription, of preparations containing cocaine; 55 of the defendants were convicted and 5 were acquitted.

Of the total number of prosecutions made, 386 resulted in conviction, 22 in acquittal; 2 were nol-prossed on a legal technicality; 13 were dismissed on motion of the inspector; and 37 are pending on appeal to the Superior Court.

The amount paid in fines was $8,300.30 which brings the sum total to $73,076.78.

PROSECUTIONS.

The following table presents the statistics relative to the prosecutions which have been conducted under the food and drug acts since the beginning of work in 1883 (Revised Laws, chapter 75, sections 16 to 27): —

Number of Complaints entered in Court.

YEAR.	Food and Other Articles (not including Milk).	Drugs.	Milk.	Total.	Convictions.	Fines imposed.
1883,	–	5	4	9	8	–[1]
1884,	2	1	45	48	44	–[1]
1885,[2]	50	1	68	119	103	–[1]
1886,[3]	10	–	10	20	19	–[1]
1887,	30	–	34	64	60	–[1]
1888,	22	–	43	65	61	$2,042 00
1889,	74	–	66	140	124	3,889 00
1890,	78	–	24	102	96	3,919 00
1891,	96	5	49	150	135	2,668 00
1892,	52	12	72	136	123	3,661 70
1893,	26	3	67	96	92	2,476 00
1894,	14	–	76	90	77	2,625 00
1895,	13	11	68	92	86	2,895 30
1896,	7	–	68	75	74	2,812 20
1897,	13	1	51	65	64	2,756 60
1898,	10	–	54	64	62	2,060 98
1899,	19	2	26	47	45	1,432 66
1900,	45	5	44	94	89	1,890 70
1901,	30	–	65	99	90	1,874 70
1902,	25	3	48	76	74	2,617 98
1903,	34	1	44	79	70	1,297 66
1904,	6	6	50	62	57	1,509 00
1905,	209	27	77	313	275	8,486 00
1906,[4]	177	60	171	409	383	7,316 00
1907,	123	63	147	333	290	6,546 00
1908,	76	138	219	433	386	8,300 30

[1] No record kept.
[2] To May 1, 1886.
[3] Four months only.
[4] Fourteen months, from Sept. 30, 1905.

For Sale of Milk not of Good Standard Quality.

Name.	Place.	Percentage of Total Solids.	Date.	Result.
Seth N. Bennett,	Agawam,	11.48	Oct. 20, 1908,	Conviction.
James Brady,	Agawam,	10.88	Oct. 16, 1908,	Conviction.
Thaddeus Fowler,	Agawam,	7.12[1]	Oct. 16, 1908,	Conviction.
Thaddeus Fowler,	Agawam,	10.58[1]	Oct. 16, 1908,	Conviction.[2]
Nicholas Hanrahan,	Agawam,	11.38	Oct. 16, 1908,	Conviction.
Henry Otto,	Agawam,	11.37	Oct. 16, 1908,	Conviction.
Alexander Mura,	Andover,	9.00[1]	May 23, 1908,	Conviction.
Emeric Pariseau,	Andover,	11.06	July 30, 1908,	Dismissed.[3]
Edward Shattuck,	Andover,	11.42	Jan. 15, 1908,	Conviction.
John Mickola,	Ashby,	10.84	Sept. 29, 1908,	Conviction.
John Seppola,	Ashby,	10.83	Sept. 29, 1908,	Conviction.
John E. Anderson,	Attleborough,	11.07	Jan. 7, 1908,	Conviction.[2]
Seneca Cole,	Attleborough,	11.54	Nov. 13, 1908,	Conviction.
Seneca Cole,	Attleborough,	11.03[1]	May 8, 1908,	Conviction.[2]
Joseph Guimond,	Attleborough,	11.17[1]	May 11, 1908,	Conviction.
Maynard C. Lewis,	Attleborough,	11.55[1]	Nov. 13, 1908,	Conviction.[2]
Maynard C. Lewis,	Attleborough,	11.55[1]	Nov. 13, 1908,	Conviction.
Geo. H. Howe,	Bedford,	11.43	Sept. 28, 1908,	Conviction.
Joseph M. Oliver,	Bedford,	7.44[1]	Aug. 18, 1908,	Conviction.
Patrick Rooney,	Bedford,	10.49[1]	Aug. 28, 1908,	Conviction.
John F. Marshall,	Beverly,	11.51	Oct. 6, 1908,	Conviction.
Wm. J. Biggerstaff,	Billerica,	11.10	Sept. 2, 1908,	Conviction.
Wm. J. Biggerstaff,	Billerica,	10.90	Aug. 12, 1908,	Conviction.
John Sullivan,	Billerica,	11.17	Jan. 16, 1908,	Conviction.
Frank L. Angell,	Boston,	12.08	Dec. 27, 1907,	Conviction.
Joseph M. LeCain,	Boston,	11.60	June 24, 1908,	Conviction.
Wm. E. Daily,	Braintree,	10.80[1]	Aug. 25, 1908,	Conviction.
Andrew T. Monahan,	Brockton,	11.00	Nov. 20, 1908,	Conviction.
George Vasho,	Brockton,	11.18[1]	Aug. 21, 1908,	Conviction.
George Vasho,	Brockton,	11.18[1]	Aug. 21, 1908,	Conviction.
Geo. W. Dinsmore,	Burlington,	10.00	July 18, 1908,	Conviction.
Otis C. Haven,	Burlington,	5.60[1]	July 18, 1908,	Conviction.
Otis C. Haven,	Burlington,	6.70[1]	July 18, 1908,	Conviction.
Charles E. O'Brien,	Burlington,	11.20	July 1, 1908,	Conviction.
Harry Barbarian,	Cambridge,	10.42	July 28, 1908,	Conviction.

[1] Addition of water alleged in complaint.
[2] Appealed to upper court; case pending.
[3] Dismissed for want of prosecution, on motion of the inspector.

For Sale of Milk not of Good Standard Quality — Continued.

Name.	Place.	Percentage of Total Solids.	Date.	Result.
Andrew Dawes,	Cambridge,	11.56	Sept. 12, 1908,	Conviction.
Thomas A. Dewire,	Cambridge,	11.60	July 28, 1908,	Conviction.
John Marinell,	Chelmsford,	7.28 [1]	July 17, 1908,	Acquittal.
Edward C. Wright,	Chelmsford,	11.07	June 16, 1908,	Conviction.
Edward C. Wright,	Chelmsford,	11.68	May 25, 1908,	Acquittal.
Samuel Schwalb,	Chelsea,	10.80	July 8, 1908,	Conviction.
James Thistle,	Chelsea,	11.84	Dec. 21, 1907,	Conviction.
Philander C. Veazie,	Chelsea,	11.65	Dec. 21, 1907,	Conviction.
Philander C. Veazie,	Chelsea,	10.64	Dec. 21, 1907,	Conviction.
Philander C. Veazie,	Chelsea,	11.34	Dec. 21, 1907,	Conviction.
Philander C. Veazie,	Chelsea,	11.60	Dec. 21, 1907,	Conviction.
John H. Baldwin,	Chicopee,	11.78	Oct. 27, 1908,	Conviction.
William Foss,	Concord,	11.28	Aug. 28, 1908,	Conviction.[2]
Alvah G. Wheeler,	Concord,	11.71	Aug. 28, 1908,	Conviction.[2]
Harry S. Wolcott,	Concord,	11.28	Aug. 28, 1908,	Conviction.[2]
Thomas F. Larrabee,	Danvers,	11.38	July 8, 1908,	Conviction.
Geo. W. Pierce,	Danvers,	9.60 [1]	July 23, 1908,	Conviction.[2]
James D. Sullivan,	Danvers,	11.20	July 8, 1908,	Acquittal.
Frank W. Webb,	Danvers,	11.24 [1]	Oct. 7, 1908,	Conviction.
Clarence H. Slocum,	Dartmouth,	10.93	July 31, 1908,	Dismissed.[3]
Frank Lawrence,	Dedham,	11.60	Sept. 9, 1908,	Conviction.
Cosmo Salenne,	Dedham,	10.00 [1]	May 18, 1908,	Acquittal.
Walter Andrew,	Dracut,	11.55	Dec. 3, 1907,	Conviction.
Carl Anderson,	East Bridgewater,	9.98 [1]	Sept. 28, 1908,	Conviction.
Carl Anderson,	East Bridgewater,	10.16 [1]	Sept. 28, 1908,	Conviction.
Archibald E. Como,	Essex,	11.60	July 16, 1908,	Conviction.
M. McKenzie,	Essex,	11.68	Jan. 24, 1908,	Conviction.
Arthur St. Laurent,	Fall River,	11.20	July 15, 1908,	Conviction.
William R. Brown,	Fitchburg,	11.40	Oct. 15, 1908,	Conviction.[2]
Ernest K. Proctor,	Fitchburg,	11.77	Jan. 6, 1908,	Dismissed.[3]
David A. Robinson,	Fitchburg,	10.80	Jan. 6, 1908,	Dismissed.[3]
Paul Sciat,	Fitchburg,	11.52	Jan. 6, 1908,	Dismissed.[3]
John A. Frye,	Gardner,	11.88	Feb. 12, 1908,	Conviction.
Albert H. Friend,	Gloucester,	11.60	July 16, 1908,	Conviction.
Albert H. Friend,	Gloucester,	11.40	July 16, 1908,	Conviction.

[1] Addition of water alleged in complaint.
[2] Appealed to upper court; case pending.
[3] Dismissed for want of prosecution, on motion of the inspector.

For Sale of Milk not of Good Standard Quality — Continued.

NAME.	Place.	Percentage of Total Solids.	Date.	Result.
Albert H. Friend,	Gloucester,	11.02	Jan. 24, 1908,	Acquittal.
John G. Nutton,	Gloucester,	11.60	July 16, 1908,	Conviction.
William Younger,	Gloucester,	10.87	July 9, 1908,	Conviction.
Albert A. Pollard,	Harvard,	10.62	Jan. 31, 1908,	Conviction.
Ulysses G. Carter,	Haverhill,	11.49	Aug. 24, 1908,	Conviction.
John W. Kimball,	Haverhill,	11.49	Aug. 24, 1908,	Conviction.
John B. Proulx,	Haverhill,	10.60	Aug. 24, 1908,	Conviction.
David T. Ray,	Haverhill,	8.60 [1]	Aug. 25, 1908,	Conviction.
David T. Ray,	Haverhill,	11.43	Aug. 25, 1908,	Conviction.
Whitney G. Brigham,	Hudson,	11.23	July 11, 1908,	Conviction.
Frank A. Melvin,	Hudson,	11.36	July 11, 1908,	Conviction.
Frank J. Rooney,	Hudson,	11.63	July 11, 1908,	Conviction.
Warren A Bailey,	Lawrence,	11.17	Oct. 21, 1908,	Conviction.
Archie Dion,	Lawrence,	10.68 [1]	Jan. 15, 1908,	Conviction. [2]
Martial G. Gagne,	Lawrence,	10.77	Oct. 21, 1908,	Acquittal.
Martial G. Gagne,	Lawrence,	11.40	Dec. 8, 1908,	Conviction. [2]
Leidger Pellerin,	Lawrence,	11.72	Jan. 15, 1908,	Conviction. [2]
Addison M. Robinson,	Lawrence,	9.86 [1]	Apr. 16, 1908,	Conviction.
Addison M. Robinson,	Lawrence,	9.86 [1]	Apr. 16, 1908,	Conviction.
Wm. E. Williams,	Lawrence,	11.37	July 23, 1908,	Conviction.
Thomas E. Kenney,	Longmeadow,	11.40	Oct. 16, 1908,	Conviction.
Thomas E. Kenney,	Longmeadow,	11.63 [1]	Oct. 16, 1908,	Conviction.
Arthur G. Boynton,	Lowell,	11.00 [1]	Jan. 30, 1908,	Dismissed. [3]
Joseph Denault,	Lowell,	11.68	July 17, 1908,	Conviction.
Leslie G. Hill,	Lowell,	11.44	Dec. 13, 1907,	Acquittal.
Joseph N. Manos,	Lowell,	11.79	Dec. 3, 1907,	Conviction.
Wm. R. McKenzie,	Lowell,	11.39	June 16, 1908,	Conviction.
Fred H. Peabody,	Lowell,	11.48	May 26, 1908,	Conviction.
Samuel P. Pike,	Lowell,	11.48	Mar. 28, 1908,	Conviction.
Samuel P. Pike,	Lowell,	11.62	June 16, 1908,	Conviction.
Herbert G. Perkins,	Lowell,	11.78	Jan. 16, 1908,	Conviction.
Joseph C. Regnier,	Lowell,	11.50	May 26, 1908,	Conviction.
Herbert H. Russell,	Lowell,	11.30	June 16, 1908,	Conviction.
Michael J. Kennedy,	Ludlow,	11.49	Oct. 16, 1908,	Conviction.
Edward C. Burnett,	Lynn,	8.08 [1]	Aug. 6, 1908,	Conviction.

[1] Addition of water alleged in complaint.
[2] Appealed to upper court; case pending.
[3] Dismissed for want of prosecution, on motion of the inspector.

For Sale of Milk not of Good Standard Quality — Continued.

Name.	Place.	Percentage of Total Solids.	Date.	Result.
Edward C. Burnett,	Lynn,	8.08 [1]	Aug. 6, 1908,	Conviction.
Patrick F. Collins,	Lynn,	11.60	July 30, 1908,	Conviction.
Joseph Foster,	Lynn,	8.72 [1]	Aug. 5, 1908,	Conviction.
Samuel Gerrish,	Lynn,	10.85 [1]	Oct. 15, 1908,	Conviction.
Wm. H. McCarthy,	Lynn,	11.49	Aug. 6, 1908,	Conviction.
Wm. H. McCarthy,	Lynn,	10.00 [1]	Aug. 6, 1908,	Conviction.
Wm. H. McCarthy,	Lynn,	11.87 [1]	Oct. 20, 1908,	Conviction.
Wm. H. McCarthy,	Lynn,	2.87 [1]	Oct. 20, 1908,	Conviction.
Wm. H. McCarthy,	Lynn,	11.80	Nov. 17, 1908,	Conviction. [2]
Joseph McLaughlin,	Lynn,	10.00 [1]	Aug. 5, 1908,	Conviction.
Hans J. Schmidt,	Lynn,	10.43 [1]	Oct. 15, 1908,	Conviction.
Elijah Hodiran,	Malden,	10.88	July 3, 1908,	Conviction.
Adelard Poudrier,	Marlborough,	10.80	May 2, 1908,	Conviction.
Joseph S. French,	Medford,	10.59 [1]	May 19, 1908,	Conviction.
Edward O. Goodridge,	Melrose,	11.62	Dec. 27, 1907,	Conviction.
Joseph M. Maidrand,	Melrose,	11.28 [1]	Oct. 20, 1908,	Conviction.
George M. Adams,	Methuen,	11.44	Mar. 20, 1908,	Conviction.
Peter Alford,	Methuen,	11.47	Jan. 15, 1908,	Conviction.
Robert E. Carleton,	Methuen,	11.46	Mar. 20, 1908,	Conviction.
Walter Clayton,	Methuen,	11.14	Oct. 21, 1908,	Dismissed. [3]
Saikes Davragin,	Methuen,	10.60 [1]	July 23, 1908,	Conviction.
Ernest Harnish,	Methuen,	11.32	Dec. 8, 1908,	Conviction.
Theodore Kiessling,	Methuen,	11.46	Jan. 15, 1908,	Conviction.
Matilda Lanouette,	Methuen,	11.24	Oct. 21, 1908,	Conviction.
John Nabed,	Methuen,	11.67	Nov. 24, 1908,	Conviction.
Mabel F. Noyes,	Methuen,	11.18	Oct. 28, 1908,	Conviction. [2]
Napoleon F. Roy,	Methuen,	11.33	July 23, 1908,	Conviction.
George Taylor,	Methuen,	11.45	Mar. 20, 1908,	Conviction.
Wm. E. Williams,	Methuen,	11.93	Jan. 15, 1908,	Conviction.
Walter F. Beal,	Milford,	11.64	Aug. 22, 1908,	Conviction.
Terrence H. Cassidy,	Millis,	11.60	Oct. 13, 1908,	Conviction.
Joseph S. Brassels,	New Bedford,	11.28	Aug. 7, 1908,	Conviction.
Frank A. Fernandes,	New Bedford,	11.65	Aug. 7, 1908,	Conviction.
Arthur Howland,	New Bedford,	11.57	July 31, 1908,	Dismissed. [3]

[1] Addition of water alleged in complaint.
[2] Appealed to upper court; case pending.
[3] Dismissed for want of prosecution; on motion of the inspector.

For Sale of Milk not of Good Standard Quality — Continued.

Name.	Place.	Percentage of Total Solids.	Date.	Result.
Charles H. Harrison,	Newbury,	11.51	Nov. 10, 1908,	Conviction.
James Noyes,	Newburyport,	10.69	Apr. 24, 1908,	Conviction.
Anthony Rogers,	North Andover,	11.28	Jan. 15, 1908,	Conviction.
Charles A. Lawrence,	Northborough,	11.30	Sept. 11, 1908,	Conviction.
Charles H. Freeman,	Norton,	10.96 [1]	May 11, 1908,	Conviction.
M. S. DeBettencourt,	Oak Bluffs,	11.66	Sept. 24, 1908,	Conviction.
Martin E. Egan,	Pittsfield,	11.31 [1]	May 28, 1908,	Acquittal.
James E. Torrey,	Pittsfield,	11.04	May 28, 1908,	Conviction.
Josiah W. Beckford,	Plymouth,	10.00 [1]	Oct. 31, 1908,	Conviction.
Fred H. Blanchard,	Plympton,	11.04	Oct. 31, 1908,	Conviction.
Wm. D. Emerson,	Reading,	10.23 [1]	Nov. 7, 1908,	Conviction.
Joseph Duhamel,	Rehoboth,	11.76	Nov. 18, 1908,	Conviction.
John J. Welch,	Rehoboth,	10.50 [1]	May 9, 1908,	Conviction.
Geo. E. Harris & Son,	Rockland,	10.90 [1]	Nov. 28, 1908,	Acquittal.
Wm. H. Evans,	Rockport,	9.49 [1]	Aug. 31, 1908,	Conviction.
Wm. H. Evans,	Rockport,	9.49 [1]	Aug. 31, 1908,	Conviction.
Herbert E. Brier,	Saugus,	10.02	Aug. 3, 1908,	Conviction. [2]
Nellie F. Burns,	Saugus,	11.22 [1]	May 7, 1908,	Conviction.
Nellie F. Burns,	Saugus,	11.63	July 10, 1908,	Conviction. [2]
Nellie F. Burns,	Saugus,	11.74	Oct. 20, 1908,	Conviction.
Nellie F. Burns,	Saugus,	11.08	Oct. 20, 1908,	Conviction.
Francis W. Clark,	Saugus,	11.48	Aug. 3, 1908,	Conviction.
Wm. P. Tilden,	Saugus,	11.26	Aug. 3, 1908,	Conviction.
Amos C. Towle,	Saugus,	11.34 [1]	Aug. 3, 1908,	Conviction.
John Walkey,	Saugus,	10.72	Aug. 3, 1908,	Conviction. [2]
Walter C. Knowlton,	Shrewsbury,	11.24	Oct. 29, 1908,	Conviction.
Joseph Gaucher,	Spencer,	11.57	June 26, 1908,	Acquittal.
Daniel Green,	Springfield,	11.32	Nov. 2, 1908,	Conviction.
Henry Otto,	Springfield,	9.45	June 3, 1908,	Acquittal.
Louis Serra,	Springfield,	11.12	June 3, 1908,	Conviction.
Louis Serra,	Springfield,	11.12	June 3, 1908,	Conviction.
Albert M. Stebbins,	Springfield,	11.42	Oct. 16, 1908,	Conviction.
Eldon Meekins,	Stoneham,	8.27 [1]	June 27, 1908,	Conviction.
Francis H. Pomeroy,	Stoneham,	11.66	June 25, 1908,	Dismissed. [3]

[1] Addition of water alleged in complaint.
[2] Appealed to upper court; case pending.
[3] Dismissed for want of prosecution, on motion of the inspector.

For Sale of Milk not of Good Standard Quality — Concluded.

Name.	Place.	Percentage of Total Solids.	Date.	Result.
Frank G. Wiley,	Stoneham,	11.06	June 27, 1908,	Conviction.
Frank Atherton,	Stoughton,	10.99	June 26, 1908,	Conviction.
Antonio Tavolier,	Sudbury,	11.00 [1]	Nov. 21, 1908,	Conviction. [2]
James Hoy,	Swansea,	11.47	July 31, 1908,	Conviction.
David S. Clarke,	Topsfield,	11.20	May 20, 1908,	Conviction.
Bill Anastos,	Tyngsborough,	10.09 [1]	Sept. 10, 1908,	Conviction.
Nathan Holbrook,	Upton,	11.27	Aug. 22, 1908,	Conviction.
Geo. W. Smith,	Wakefield,	10.08 [1]	July 2, 1908,	Conviction.
Lester J. Carter,	Waltham,	11.13	Mar. 26, 1908,	Conviction.
Walter B. Jourdan,	Westborough,	10.70	July 22, 1908,	Conviction.
Hyacinth LeDuc,	Westford,	11.50	Oct. 14, 1908,	Conviction.
Fred L. McCoy,	Westford,	10.96	Oct. 14, 1908,	Conviction.
William Leach,	Westminster,	10.77 [1]	Feb. 12, 1908,	Conviction.
Frank C. Vieria,	Westport,	11.60	July 15, 1908,	Conviction.
Michael Beauregard,	West Springfield,	11.68	Oct. 27, 1908,	Conviction.
Frank Marar,	West Springfield,	10.98	Oct. 27, 1908,	Conviction.
Harris Goldberg,	Warren,	11.80	Feb. 10, 1908,	Conviction.
Joseph P. Hubert,	Warren,	11.80	Feb. 10, 1908,	Conviction.
William Burhoe,	Whitman,	11.27	Nov. 23, 1908,	Acquittal.
Arlon D. Bailey,	Winchendon,	8.23 [1]	Aug. 6, 1908,	Conviction.
Waldo F. Streeter,	Winchendon,	8.23 [1]	Aug. 6, 1908,	Conviction.
Mathew J. Bennett,	Woburn,	11.80	May 6, 1908,	Conviction.
Albert E. Kenneson,	Woburn,	10.08 [1]	July 11, 1908,	Conviction.
Albert E. Kenneson,	Woburn,	11.00	July 11, 1908,	Conviction.
Albert E. Kenneson,	Woburn,	12.14	Dec. 19, 1908,	Conviction.
Albert E. Kenneson,	Woburn,	12.26	Dec. 19, 1908,	Conviction.
Michael McDevitt,	Woburn,	9.02 [1]	Aug. 19, 1908,	Conviction.
Wm. J. Whalen,	Woburn,	11.74	Dec. 10, 1908,	Conviction.
Hugo P. Findensen,	Salem Depot, N. H.,	11.74	Jan. 15, 1908,	Conviction.

[1] Addition of water alleged in complaint.
[2] Appealed to upper court; case pending.

For Sale of Milk containing Added Foreign Matter.

NAME.	Place.	Adulterant.	Date.	Result.
Howard R. Lefavour, .	Beverly, . .	Formaldehyde, .	Oct. 14, 1908,	Conviction.
Howard R. Lefavour, .	Beverly, . .	Formaldehyde, .	Oct. 14, 1908,	Conviction.
Nellie F. Burns, . .	Saugus, . .	Coloring matter, .	Nov. 17, 1908,	Acquittal.
Nellie F. Burns, . .	Saugus, . .	Coloring matter, .	Oct. 20, 1908,	Conviction.
Nellie F. Burns, . .	Saugus, . .	Coloring matter, .	Nov. 17, 1908,	Conviction.
Frank N. Besson, .	Swampscott, .	Formaldehyde, .	Oct. 15, 1908,	Conviction.
Frank N. Besson, .	Swampscott, .	Formaldehyde, .	Oct. 15, 1908,	Conviction.

For returning Milk Cans containing Offensive Material.

NAME.	Place.	Date.	Result.
Boston Dairy Company, ...	Boston, . . .	Sept. 24, 1908,	Conviction.[1]
Boston Dairy Company, ...	Boston, . . .	Sept. 24, 1908,	Conviction.[1]
Boston Dairy Company, ...	Boston, . . .	Sept. 24, 1908,	Conviction.[1]

For Obstruction of Inspector.

Wm. J. Biggerstaff, ...	Billerica, . . .	Sept. 2, 1908,	Conviction.
Frank H. Cornell, ...	New Bedford, . .	Aug. 7, 1908,	Conviction.[1]

[1] Appealed to upper court; case pending.

For Sale of Adulterated Cream.

NAME.	Place.	Adulterant.	Date.	Result.
George Dee, . .	Lynn, . .	Calcium sucrate and cane sugar.	Nov. 28, 1908,	Conviction.
Richard J. Borden, .	Quincy, . .	Calcium sucrate, .	Dec. 2, 1908,	Acquittal.
Wm. F. Hodgkinson, .	Quincy, . .	Calcium sucrate, .	Nov. 16, 1908,	Dismissed.[1]
John W. Davies, .	Reading, . .	Calcium sucrate, .	Nov. 7, 1908,	Conviction.

[1] Dismissed for want of prosecution, on motion of the inspector.

For Sale of Oleomargarine as Butter.

NAME.	Place.	Date.	Result.
William Smith, ...	Beverly, . . .	Mar. 24, 1908,	Conviction.

For Sale of Adulterated Foods Other than Milk and Milk Products.

HAMBURG STEAK.

NAME.	Place.	Adulterant.	Date.	Result.
Edward O. Harlow,	Ayer,	Sulphurous acid,	Feb. 3, 1908,	Conviction.
Benjamin Berensen,	Boston,	Sulphurous acid,	Mar. 11, 1908,	Acquittal.
Henry Curtis,	Boston,	Sulphurous acid,	Sept. 30, 1908,	Conviction.[1]
Israel Kosofski,	Boston,	Sulphurous acid,	Mar. 31, 1908,	Conviction.
Geo. W. Milliken,	Boston,	Sulphurous acid,	Mar. 31, 1908,	Conviction.
Simon Piletsky,	Boston,	Sulphurous acid,	Dec. 3, 1908,	Conviction.
Truman D. Thorpe,	Boston,	Sulphurous acid,	Mar. 24, 1908,	Conviction.
John Beauregard,	Brockton,	Sulphurous acid,	Nov. 20, 1908,	Conviction.[1]
Daniel W. Case,	Brockton,	Sulphurous acid,	Nov. 20, 1908,	Conviction.[1]
Benjamin V. Loud,	Brockton,	Sulphurous acid,	Nov. 20, 1908,	Conviction.[1]
Joseph Pessetti,	Chelsea,	Sulphurous acid,	Jan. 9, 1908,	Conviction.
Arthur Peel,	Lawrence,	Sodium sulphite,	July 16, 1908,	Conviction.
George R. Myers,	Lowell,	Sulphurous acid,	Mar. 21, 1908,	Conviction.
George Richards,	Lowell,	Sulphurous acid,	Jan. 16, 1908,	Conviction.
James Smith,	Lowell,	Sulphurous acid,	May 16, 1908,	Conviction.
James Smith,	Lowell,	Sulphurous acid,	Dec. 13, 1907,	Conviction.
W. Edgar Carter,	Lynn,	Sodium sulphite,	July 24, 1908,	Conviction.
Joseph J. Healy,	Lynn,	Sulphurous acid,	May 19, 1908,	Conviction.[1]
Edgar W. Butterworth,	Salem,	Sulphurous acid,	Oct. 14, 1908,	Conviction.[1]

SAUSAGE.

Herbert B. Hathaway,	Arlington,	Sulphurous acid,	Dec. 11, 1908,	Conviction.
Herbert B. Hathaway,	Arlington,	Sulphurous acid,	Dec. 11, 1908,	Conviction.
Herbert B. Hathaway,	Arlington,	Sulphurous acid,	Dec. 11, 1908,	Conviction.
Herbert B. Hathaway,	Arlington,	Sulphurous acid,	Dec. 11, 1908,	Conviction.

PICKLES.

Herbert G. Dunmire,	Boston,	Alum,	Apr. 28, 1908,	Conviction.

CHILI SAUCE.

George H. Bosch,	Lawrence,	Benzoic acid,	Mar. 20, 1908,	Conviction.

[1] Appealed to upper court; case pending.

For Sale of Adulterated Foods Other than Milk and Milk Products — Continued.

VINEGAR.

Name.	Place.	Adulterant.	Date.	Result.
Chas. G. Mullen,	Quincy,	Not pure cider vinegar.	Dec. 16, 1907,	Conviction.
Downing, Taylor Company.	Springfield,	Not pure cider vinegar.	June 3, 1908,	Conviction.
E. O. Smith Company,	Springfield,	Not pure cider vinegar.	June 3, 1908,	Conviction.
Sturtevant & Merrick Company.	Springfield,	Not pure cider vinegar.	June 3, 1908,	Conviction.

JAMS AND JELLIES.

Francis P. Adams,	Boston,	Benzoic acid,	Dec. 18, 1907,	Conviction.
Gregory MacLeod,	Boston,	Benzoic acid,	Dec. 18, 1907,	Conviction.
George H. Bosch,	Lawrence,	Benzoic acid,	Mar. 20, 1908,	Conviction.

MAPLE SUGAR.

Anastos Anastos .	Boston,	Cane sugar,	July 14, 1908,	Conviction.
Stephen Costa,	Boston,	Cane sugar,	Apr. 14, 1908,	Conviction.
Christos Lykos,	Boston,	Cane sugar,	Mar. 31, 1908,	Conviction.
George Zevitar,	Boston,	Cane sugar,	July 14, 1908,	Conviction.

MAPLE SYRUP.

John Goodwin,	Lowell,	Cane sugar,	Dec. 13, 1907,	Conviction.

CIDER.

James O. Holt,	Arlington,	Benzoic acid,	Dec. 24, 1907,	Conviction.
Walter K. Hutchinson,	Arlington,	Benzoic acid,	Dec. 24, 1907,	Conviction.
Charles G. Sloan,	Arlington,	Benzoic acid,	Jan. 1, 1908,	Conviction.
Harry G. Blanchard,	Boston,	Benzoic acid,	Feb. 21, 1908,	Conviction.
Joseph J. Curran,	Boston,	Benzoic acid,	Feb. 26, 1908,	Conviction.
Haynes-Piper Company,	Boston,	Benzoic acid,	May 28, 1908,	Conviction.
John F. Henry,	Boston,	Benzoic acid,	Feb. 19, 1908,	Conviction.
Venna F. Lott,	Boston,	Benzoic acid,	Feb. 21, 1908,	Conviction.
Eugene F. McAuliffe,	Boston,	Benzoic acid,	Feb. 19, 1908,	Conviction.
Sylvester Santospirito,	Boston,	Benzoic acid,	Apr. 2, 1908,	Conviction.
Chas. E. Sleeper,	Boston,	Benzoic acid,	Mar. 13, 1908,	Conviction.
Albert H. Cushman,	Bridgewater,	Salicylic acid,	May 1, 1908,	Conviction.
Zebulon P. Cushman,	Bridgewater,	Salicylic acid,	May 1, 1908,	Conviction.

For Sale of Adulterated Foods Other than Milk and Milk Products — Continued.

CIDER — Concluded.

Name.	Place.	Adulterant.	Date.	Result.
John J. Coffey,	Cambridge,	Benzoic acid,	Feb. 5, 1908,	Conviction.
Clarence H. Hobden,	Chelsea,	Benzoic acid,	Feb. 8, 1908,	Conviction.
Kayajan A. Simonds,	Chelsea,	Benzoic acid,	Feb. 8, 1908,	Dismissed.[1]
Boyle Bros.,	Lowell,	Benzoic acid,	Dec. 13, 1907,	Conviction.
John H. Donnelly,	Lowell,	Benzoic acid,	Jan. 30, 1908,	Conviction.
Martin W. Halloran,	Lowell,	Benzoic acid,	Jan. 30, 1908,	Conviction.
Charles H. Joyce Company.	Lowell,	Benzoic acid,	Feb. 11, 1908,	Conviction.
John J. Kennedy,	Lowell,	Benzoic acid,	Jan. 30, 1908,	Conviction.
Middlesex Grocery Company.	Lowell,	Benzoic acid,	Feb. 11, 1908,	Conviction.
Joseph B. Thornton,	Lowell,	Benzoic acid,	July 17, 1908,	Conviction.
Fredk. E. Bruce,	Melrose,	Benzoic acid,	Jan. 3, 1908,	Conviction.
Oliver E. Hawes,	Melrose,	Benzoic acid,	Jan. 3, 1908,	Conviction.
Sidney W. Taylor,	Melrose,	Benzoic acid,	Jan. 3, 1908,	Conviction.
Edney A. Lapham,	New Bedford,	Salicylic acid,	July 24, 1908,	Conviction.[2]
Charles Cetlin,	Newburyport,	Benzoic acid,	Apr. 24, 1908,	Conviction.
George A. Wells,	Salem,	Benzoic acid,	Feb. 29, 1908,	Nol-prossed.
Clarence W. Goldwait,	Somerville,	Benzoic acid,	Feb. 6, 1908,	Conviction.
Nathaniel E. Cutler,	Wakefield,	Benzoic acid,	Jan. 3, 1908,	Conviction.

GRAPE JUICE.

Thomas Dean,	Boston,	Salicylic acid,	Feb. 8, 1908,	Conviction.
Chas. E. Sleeper,	Boston,	Alcohol,	Mar. 13, 1908,	Conviction.

CONDENSED MILK.

Sherman E. Hollister,	Boston,	Fat in original milk 1.8 per cent.	Feb. 21, 1908,	Dismissed.[1]

EXTRACT OF COFFEE.

Ferdinand E. Sage,	Boston,	Benzoic acid,	July 8, 1908,	Conviction.
Udelpha V. Sage,	Boston,	Benzoic acid,	July 14, 1908,	Conviction.

FRUIT EXTRACTS.

John M. Deane,	Fall River,	Water, fusel oil derivatives and coloring matter.	July 31, 1908,	Conviction.
John M. Deane,	Fall River,	Aldehyde and coloring matter.	July 31, 1908,	Conviction.

[1] Dismissed for want of prosecution, on motion of the inspector.
[2] Appealed to upper court; case pending.

For Sale of Adulterated Foods Other than Milk and Milk Products — Concluded.

PEPPER.

NAME.	Place.	Adulterant.	Date.	Result.
Harry L. Lord, . .	Chelsea, . .	Peas and wheat, .	Jan. 23, 1908.	Conviction.

For Sale of Adulterated Drugs.

ALCOHOL.

Michael J. Ganon, .	Adams, . .	Water, . .	June 4, 1908,	Conviction.
Abraham Berkman, .	Boston, . .	Water, . .	Feb. 26, 1908,	Conviction.
Austin L. Cannon, .	Boston, . .	Water, . .	Mar. 19, 1908,	Conviction.
Isaac Cartoof, . .	Boston, . .	Water, . .	Feb. 26, 1908,	Conviction.
Duncan J. Chisholm, .	Boston, . .	Water, . .	Feb. 21, 1908,	Conviction.
Henry C. Cobe, . .	Boston, . .	Water, . .	Feb. 21, 1908,	Conviction.
Thomas Cox, . .	Boston, .	Water, . .	Feb. 21, 1908,	Conviction.
Mark H. Crehan, .	Boston, . .	Water, . .	Feb. 21, 1908,	Conviction.
Mark H. Crehan, .	Boston, . .	Water, . .	Mar. 11, 1908,	Conviction.
Joseph Dine, . .	Boston, . .	Water, . .	Mar. 26, 1908,	Conviction.
Thomas F. Doherty, .	Boston, . .	Water, . .	Feb. 26, 1908,	Nol-prossed.
Simon Flashman, .	Boston, . .	Water, . .	Feb. 26, 1908,	Conviction.
Israel Goldstein, . .	Boston, . .	Water, . .	Feb. 26, 1908,	Conviction.
Jesse Goode, . .	Boston, . .	Water, . .	Feb. 18, 1908,	Conviction.
James H. Griffin,. .	Boston, . .	Water, . .	Apr. 9, 1908,	Conviction.
John J. Healy, . .	Boston, . .	Water, . .	Mar. 5, 1908,	Conviction.
David Henry, . .	Boston, . .	Water, . .	Apr. 15, 1908,	Conviction.
Wm. J. Higgins, . .	Boston, . .	Water, . .	Apr. 9, 1908,	Conviction.
John F. Holland,. .	Boston, . .	Water, . .	Mar. 25, 1908,	Conviction.
William B. Huber, .	Boston, . .	Water, . .	Feb. 18, 1908,	Conviction.
Henry J. Joyce, . .	Boston, . .	Water, . .	Feb. 18, 1908,	Conviction.
Joseph J. Kelly, . .	Boston, . .	Water, . .	Apr. 15, 1908,	Conviction.
John H. Lane, . .	Boston, . .	Water, . .	May 22, 1908,	Conviction.
John R. Magullion, .	Boston, . .	Water, . .	Mar. 19, 1908,	Conviction.
John McWeeny, . .	Boston, . .	Water, . .	Feb. 25, 1908,	Conviction.[1]
Thos. J. Mitchell, .	Boston, . .	Water, . .	Mar. 11, 1908,	Conviction.
Myer Myers, . .	Boston, . .	Water, . .	Feb. 26, 1908,	Conviction.
James F. O'Neil, .	Boston, . .	Water, . .	Mar. 17, 1908,	Conviction.
Adolph G. Pearce, .	Boston, . .	Water, . .	Feb. 26, 1908,	Conviction.
Andrew F. Pendergast,	Boston, . .	Water, . .	Feb. 21, 1908,	Conviction,
Frederick A. Perry, .	Boston, . .	Water, . .	Feb. 26, 1908,	Conviction.

[1] Appealed to upper court; case pending.

For Sale of Adulterated Drugs — Continued.

ALCOHOL — Concluded.

Name.	Place.	Adulterant.	Date.	Result.
Solomon Pinkofsky,	Boston,	Water,	Feb. 21, 1908,	Conviction.
Frederick F. Ryan,	Boston,	Water,	Feb. 24, 1908,	Conviction.
Joseph P. Spang,.	Boston,	Water,	May 12, 1908,	Conviction.
Harry Staples,	Boston,	Water,	Feb. 21, 1908,	Conviction.
Benjamin Starr,	Boston,	Water,	Mar. 11, 1908,	Conviction.
Jacob Swarts,	Boston,	Water,	Feb. 26, 1908,	Conviction.
John Tobin,	Boston,	Water,	Feb. 26, 1908,	Conviction.
Ike Zeigler,.	Boston,	Water,	Feb. 21, 1908,	Conviction.
James P. Derby,	Fitchburg,.	Water,	Dec. 26, 1907,	Conviction.
Hugh F. Broderick,	Ipswich,	Water,	Dec. 19, 1907,	Conviction.
Thos. J. Broderick,	Ipswich,	Water,	Dec. 19, 1907,	Conviction.
William Mayer,	Ipswich,	Water,	Dec. 28, 1907,	Conviction.
Michael Carney,	Lawrence,	Water,	Mar. 12, 1908,	Conviction.
Daniel F. Conlin,.	Lawrence,	Water,	Feb. 7, 1908,	Conviction.
John Ford,	Lawrence,	Water,	Feb. 7, 1908,	Conviction.
Henry J. Koellen,	Lawrence,	Water,	Mar. 12, 1908,	Conviction.
Charles W. Brackett,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
John B. Collins,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
James Dempsey,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
Edward Heffernan,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
Richard J. Kane,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
David J. Keliher,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
Frank H. Lindley,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
John McMahon,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
James Nicholson,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
Loren M. Rollins,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
Philip W. Ward,	Lynn,	Water,	Apr. 8, 1908,	Conviction.
Thomas Quinn,	North Adams,	Water,	May 21, 1908,	Conviction.
Joseph A. Rosi,	North Adams,	Water,	May 21, 1908,	Conviction.
Joseph C. Oxley,	Reading,	Water,	Feb. 8, 1908,	Conviction.
Cornelius Murphy,	Springfield,	Water,	June 3, 1908,	Acquittal.
William Young,	Springfield,	Water,	June 3, 1908,	Conviction.

BEESWAX.

William B. Burke,	Lowell,	Paraffine,	Jan. 30, 1908,	Conviction.
Albert E. Moors,	Lowell,	Paraffine,	Dec. 13, 1907,	Conviction.

For Sale of Adulterated Drugs — Continued.

BORAX.

NAME.	Place.	Adulterant.	Date.	Result.
Max Braman, . .	Boston, . .	Sodium bi-carbonate.	Dec. 31, 1907,	Conviction.

COCAINE HYDROCHLORIDE.

Thomas Davies, . .	Boston, . .	Unlabelled, . .	July 14, 1908,	Conviction.
Thomas Davies, . .	Boston, . .	Unlabelled, . .	July 14, 1908,	Conviction.
Thomas Davies, . .	Boston, . .	Unlabelled, . .	July 14, 1908,	Conviction.
Thomas Davies, . .	Boston, . .	Unlabelled, . .	July 14, 1908,	Conviction.
John F. Kershaw, .	Boston, . .	Unlabelled, . .	June 19, 1908,	Conviction.
John F. Kershaw, .	Boston, . .	Unlabelled, . .	July 14, 1908,	Conviction.
John F. Kershaw, .	Boston, . .	Unlabelled, . .	July 14, 1908,	Conviction.
James L. Mooney, .	Boston, . .	Unlabelled, . .	Sept. 2, 1908,	Conviction.
Scott & McCobb, .	Boston, . .	Unlabelled, . .	July 14, 1908,	Conviction.

CAMPHORATED OIL.

Edward L. Hurley, .	Boston, . .	Deficiency in strength.	Jan. 31, 1908,	Conviction.

OLIVE OIL.

Michael J. Ajamian, .	Boston, . .	Cotton-seed oil, .	Apr. 14, 1908,	Conviction.
Frank E. Shea, . .	Boston, . .	Cotton-seed oil, .	Sept. 23, 1908,	Conviction.

SPIRIT OF CAMPHOR.

Edward L. Hurley, .	Boston, . .	Deficiency in strength.	Jan. 31, 1908,	Conviction.
Robert J. Smythe, .	Boston, . .	Deficiency in strength.	Dec. 18, 1907,	Conviction.
Jonas S. Chalmarson, .	Lowell, . .	Deficiency in strength.	Dec. 13, 1907,	Acquittal.

SPIRIT OF PEPPERMINT.

Frederick L. Pratt, .	Boston, . .	Deficiency in strength.	Feb. 21, 1908,	Conviction.
Albert J. Soderstrom, .	Fitchburg, .	Deficiency in strength.	Jan. 6, 1908,	Conviction.

For Sale of Adulterated Drugs — Continued.

Tincture of Iodine.

Name.	Place.	Adulterant.	Date.	Result.
Felice Lauricella,	Boston,	Deficiency in strength.	Dec. 4, 1908,	Conviction.
Lafayette J. Mathieu,	Boston,	Deficiency in strength.	Nov. 3, 1908,	Dismissed.[1]
Andrew E. Burke,	Lawrence,	Deficiency in strength.	June 23, 1908,	Conviction.
Sanford H. Plumb,	North Adams,	Deficiency in strength.	June 9, 1908,	Acquittal.

Wine of Coca.

Asro W. Dows,	Lowell,	Cocaine,	Dec. 3, 1907,	Conviction.

Metcalf's Coca Wine.

Geo. R. Whitcher,	Medford,	Cocaine,	Jan. 21, 1908,	Conviction.

Maltine with Coca Wine.

Elmer R. Abbott,	Danvers,	Cocaine,	Dec. 14, 1907,	Conviction.
Wm. E. Conway,	Lowell,	Cocaine,	Jan. 16, 1908,	Conviction.
Alard J. Payette,	Lowell,	Cocaine,	Dec. 3, 1907,	Conviction.
Frank B. Case,	Medford,	Cocaine,	Jan. 22, 1908,	Conviction.
Alrich B. Swensson,	Melrose,	Cocaine,	Jan. 21, 1908,	Conviction.
Eugene W. Benjamin,	Reading,	Cocaine,	Jan. 29, 1908,	Conviction.
Wm. E. McLaughlin,	Woburn,	Cocaine,	Jan. 18, 1908,	Conviction.

Catarrh Remedies.

Melvin B. Buckley,	Boston,	Cocaine,	Feb. 6, 1908,	Conviction.
Cornelius Callahan,	Boston,	Cocaine,	Apr. 6, 1908,	Conviction.
Walter L. Conwell,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.[2]
James J. Cramer,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.
James J. Cramer,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.
James J. Cramer,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.
Edward Driscoll,	Boston,	Cocaine,	Apr. 1, 1908,	Conviction.[2]
Edward Driscoll,	Boston,	Cocaine,	Apr. 1, 1908,	Conviction.[2]
Edward Driscoll,	Boston,	Cocaine,	Apr. 1, 1908,	Conviction.[2]
Herbert L. Erskine,	Boston,	Cocaine,	Mar. 18, 1908,	Conviction.
Herbert L. Erskine,	Boston,	Cocaine,	Mar. 18, 1908,	Conviction.
Fred A. Ewell,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.

[1] Dismissed for want of prosecution, on motion of the inspector.
[2] Appealed to upper court; case pending.

For Sale of Adulterated Drugs — Concluded.

CATARRH REMEDIES — Concluded.

NAME.	Place.	Adulterant.	Date.	Result.
Fred A. Ewell,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.
Fred A. Ewell,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.
Eugene Harriman,	Boston,	Cocaine,	Jan. 7, 1908,	Conviction.
John W. Hawkins,	Boston,	Cocaine,	Mar. 7, 1908,	Acquittal.
Wm. Hennessey,	Boston,	Cocaine,	Apr. 1, 1908,	Conviction.[1]
Joseph E. Lombardi,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.
James Malloy,	Boston,	Cocaine,	Apr. 1, 1908,	Conviction.[1]
James Malloy,	Boston,	Cocaine,	Apr. 1, 1908,	Conviction.[1]
Joseph McGraw,	Boston,	Cocaine,	Feb. 24, 1908,	Conviction.
Harry Naldrett,	Boston,	Cocaine,	Mar. 25, 1908,	Conviction.
Geo. F. Ramponi,	Boston,	Cocaine,	Mar. 19, 1908,	Conviction.
Louis Richards,	Boston,	Cocaine,	Mar. 25, 1908,	Conviction.
Frank E. Shea,	Boston,	Cocaine,	Mar. 16, 1908,	Conviction.
Frank E. Shea,	Boston,	Cocaine,	Mar. 16, 1908,	Conviction.
Samuel Molin,	Chelsea,	Cocaine,	Apr. 6, 1908,	Conviction.
Samuel Molin,	Chelsea,	Cocaine,	Apr. 6, 1908,	Conviction.
Samuel Molin,	Chelsea,	Cocaine,	Apr. 6, 1908,	Conviction.
Ernest G. Kelly,	Lynn,	Cocaine,	Dec. 23, 1907,	Conviction.
Ernest Kelly,	Lynn,	Cocaine,	Mar. 2, 1908,	Conviction.
Ernest Kelly,	Lynn,	Cocaine,	Mar. 2, 1908,	Conviction.
Ernest Kelly,	Lynn,	Cocaine,	Mar. 2, 1908,	Conviction.

CELERINA.

NAME.	Place.	Adulterant.	Date.	Result.
Francis E. Mole,	Adams,	Cocaine,	May 29, 1908,	Acquittal.
Edward Riley,	Adams,	Cocaine,	May 29, 1908,	Acquittal.
J. W. Krum, Jr.,	North Adams,	Cocaine,	May 21, 1908,	Acquittal.
Arthur F. Lee,	North Adams,	Cocaine,	May 21, 1908,	Conviction.
James Morin,	North Adams,	Cocaine,	May 21, 1908,	Acquittal.
Joseph E. Triganne,	North Adams,	Cocaine,	May 21, 1908,	Conviction.
Frank M. Casey,	Pittsfield,	Cocaine,	May 28, 1908,	Conviction.
Durgin McManus Company,	Pittsfield,	Cocaine,	May 28, 1908,	Conviction.
Edward F. Fahey,	Pittsfield,	Cocaine,	May 28, 1908,	Conviction.

[1] Appealed to upper court; case pending.

Of the cases reported as pending in the last preceding report, 7 for the sale of adulterated milk resulted in conviction, fines having been imposed

in all but 1 case; 2 other cases resulted in acquittal. One case each for the sale of adulterated Hamburg steak, alcohol and tincture of iodine resulted in conviction and fine. One other case then pending is still to be tried.

The amount paid in fines was $8,300.30, as follows: —

Milk and milk products,	$3,744 80
Foods other than above,	1,512 50
Drugs,	3,043 00
	$8,300 30

Expenditures under the Provisions of the Food and Drug Acts for the Year ended Nov. 30, 1908.

Appropriation,	$14,500 00
Salaries of analysts,	$5,833 33
Salaries of inspectors,	4,628 09
Travelling expenses and purchase of samples,	2,207 72
Apparatus and chemicals,	934 69
Printing,	142 10
Services, cleaning laboratory,	106 00
Express, telephone and telegraph messages,	21 87
Sundry laboratory supplies,	114 22
Books and maps,	41 70
Extra services,	352 50
Advertising,	63 22
Miscellaneous,	19 52
Total,	$14,464 96

Respectfully submitted,

WM. C. HANSON,
Acting Secretary.

REPORT OF THE ANALYST.

By Hermann C. Lythgoe.

REPORT OF THE ANALYST.

By Hermann C. Lythgoe.

Dr. William C. Hanson, *Acting Secretary of the Massachusetts State Board of Health.*

Dear Sir: — I herewith submit my report on the analysis of food and drugs for the year ending Nov. 30, 1908.

Milk and Milk Products.

Three thousand nine hundred and thirty-four samples of milk were examined during the year, of which 2,764 conformed to the statute requirements. The usual statistics of milk are as follows: —

Milk from Cities.

Cities.	Number above Standard.	Number below Standard.	Total Samples collected.	Total Solids in Lowest Sample (Per Cent.).	Number of Skimmed Samples.	Number of Samples colored with Annatto.	Number of Samples preserved with Formaldehyde.	Number of Samples which contained Added Water.
Beverly,	49	9	58	11.51	-	-	1	-
Brockton,	78	22	100	9.98	-	-	-	3
Cambridge,	77	15	92	10.42	-	-	-	-
Chelsea,	29	31	60	10.64	-	-	-	-
Chicopee,	27	7	34	10.98	-	-	-	-
Everett,	15	-	15	12.12	-	-	-	-
Fall River,	49	20	69	10.09	1	-	-	-
Fitchburg,	10	7	17	11.40	-	-	-	-
Gloucester,	83	30	113	10.36	-	-	-	1
Haverhill,	23	31	54	8.60	-	-	-	2
Holyoke,	31	2	33	12.00	-	-	-	-
Lawrence,	77	109	186	9.00	8	-	-	6
Lowell,	92	41	133	9.76	1	-	-	2
Lynn,	77	31	108	8.08	-	-	1	7
Malden,	29	15	44	10.88	-	-	-	-
Marlborough,	37	10	47	10.80	-	-	-	-
Medford,	22	8	30	10.72	-	-	-	-
Melrose,	28	42	70	2.87	-	5	-	8
New Bedford,	78	18	96	10.93	-	-	-	1
Newburyport,	39	19	58	11.27	-	-	-	-
Newton,	19	4	23	12.10	-	-	-	-
North Adams,	39	1	40	9.48	1	-	-	-
Northampton,	8	7	15	12.40	-	-	-	-
Pittsfield,	25	3	28	11.04	-	-	-	1
Quincy,	48	9	57	10.80	-	-	-	1
Salem,	59	16	75	11.20	-	-	-	3
Somerville,	28	14	42	11.88	-	-	-	-
Springfield,	57	42	99	9.62	-	-	-	7
Taunton,	19	7	26	10.50	1	-	-	1
Waltham,	57	15	72	11.13	2	-	-	-
Woburn,	29	32	61	9.02	-	-	-	2
Worcester,	29	14	43	9.86	1	-	-	-
Summary,	1,367	631	1,998	2.87	10	5	2	45

Milk from Towns.

Towns.	Number above Standard.	Number below Standard.	Total Samples collected.	Total Solids in Lowest Sample (Per Cent.).	Number of Skimmed Samples.	Number of Samples which contained Added Water.
Abington,	25	2	27	11.65	-	-
Acton,	16	5	21	11.86	-	-
Adams,	18	-	18	12.20	-	-
Amesbury,	16	1	17	11.47	-	-
Andover,	16	8	24	11.54	1	-
Arlington,	7	2	9	11.83	-	-
Athol,	10	-	10	12.92	-	-
Attleborough,	36	19	55	10.63	1	6
Ayer,	3	-	3	12.28	-	-
Barnstable,	5	1	6	11.24	-	-
Blackstone,	1	2	3	12.46	-	-
Braintree,	24	2	26	9.56	-	1
Bridgewater,	14	1	15	12.06	-	-
Brookline,	19	2	21	12.30	-	-
Canton,	8	-	8	12.80	-	-
Chelmsford,	6	3	9	8.63	-	2
Clinton,	21	4	25	9.50	3	-
Cohasset,	10	1	11	12.00	-	-
Danvers,	55	7	62	9.60	-	1
Dedham,	18	1	19	10.00	-	1
Easton,	15	1	16	10.20	-	-
Framingham,	19	1	20	11.40	-	-
Franklin,	2	-	2	12.30	-	-
Gardner,	16	7	23	10.77	-	1
Greenfield,	16	1	17	12.08	-	-
Hingham,	23	-	23	12.23	-	-
Hopkinton,	1	-	1	12.62	-	-
Hudson,	13	14	27	9.24	1	-
Hyde Park,	29	1	30	11.90	-	-
Ipswich,	19	2	21	9.82	-	2
Mansfield,	9	2	11	11.45	-	-
Marblehead,	40	2	42	11.60	-	-
Methuen,	7	8	15	9 70	1	-
Middleborough,	11	-	11	12.70	-	-
Milford,	72	8	80	9.68	-	2
Natick,	6	9	15	12.45	-	-
Needham,	6	-	6	12.60	-	-

Milk from Towns — Concluded.

Towns.	Number above Standard.	Number below Standard.	Total Samples collected.	Total Solids in Lowest Sample (Per Cent.).	Number of Skimmed Samples.	Number of Samples which contained Added Water.
North Andover, . . .	4	12	16	12.40	-	-
North Attleborough, . .	20	5	29	9.64	1	-
Norton, ...	4	1	5	11.85	-	-
North Reading, . . .	-	2	2	11.98	-	-
Norwood, ...	22	16	38	11.28	-	-
Oak Bluffs, . . .	9	1	10	11.66	-	-
Orange, ...	17	-	17	12.20	-	-
Peabody, ...	26	13	39	9.52	-	1
Plymouth, ...	25	5	30	10.00	-	1
Reading, ...	28	-	28	9.83	3	-
Rehoboth, ...	2	2	4	11.76	-	-
Revere, ...	14	2	16	10.40	-	-
Rockland, ...	12	1	13	10.90	-	1
Rockport, ...	13	5	18	10.82	-	1
Saugus, ...	10	9	19	10.58	-	1
Sharon, ...	1	-	1	13.30	-	-
Southbridge, . . .	15	2	17	11.74	-	-
Spencer, ...	26	2	28	11.58	-	-
Stoneham, ...	22	12	34	8.27	-	4
Stoughton, ...	25	5	30	11.70	-	-
Swampscott, . . .	11	-	11	12.26	-	-
Turners Falls, . . .	14	2	16	11.64	-	-
Wakefield, ...	12	-	12	12.47	-	-
Ware, ...	22	6	28	11.80	-	-
Warren, ...	5	6	11	11.80	-	-
Watertown, . . .	12	6	18	12.45	-	-
Webster, ...	21	1	22	11.68	-	-
Wellesley, ...	7	1	8	11.73	-	-
Westborough, . . .	14	1	15	10.70	-	-
Westford, ...	6	3	9	10.96	-	-
Weymouth, . . .	7	2	9	8.92	-	1
Whitman, ...	41	6	47	11.27	-	-
Williamstown, . . .	9	-	9	9.52	1	-
Winchendon, . . .	24	3	27	8.23	-	1
Winchester, . . .	12	7	19	11.33	-	-
Winthrop, ...	16	-	16	12.14	-	-
Summary, . . .	1,164	256	1,420	8.23	12	27

Milk from Suspected Producers.

Locality.	Number above Standard.	Number below Standard.	Total Samples collected.	Total Solids in Lowest Sample (Per Cent.).	Number of Samples which contained Added Water.
Andover,	4	17	21	9.00	3
Ashby,	11	6	17	10.83	-
Bedford,	14	25	39	7.44	9
Billerica,	2	2	4	10.90	-
Burlington,	14	20	34	5.60	7
Chelmsford,	1	7	8	11.68	-
Concord,	4	12	16	11.28	-
Dedham,	11	8	19	11.60	-
Groveland,	4	2	6	12.60	-
Harvard,	1	9	10	10.62	-
Lawrence,	6	9	15	11.40	1
Mansfield,	3	-	3	12.14	-
Methuen,	10	39	49	11.65	4
Millis,	1	8	9	11.60	-
North Andover,	2	2	4	11.17	-
Northborough,	3	7	10	11.30	-
Reading,	15	2	17	10.23	2
Rehoboth,	23	12	35	10.50	6
Saugus,	-	1	1	12.14	-
Shrewsbury,	-	12	12	11.24	-
Sudbury,	-	4	4	11.00	3
Topsfield,	8	3	11	11.20	-
Tyngsborough,	-	16	16	10.09	16
Wakefield,	-	3	3	10.08	2
Wenham,	2	-	2	12.08	-
Westford,	3	13	16	10.96	-
West Springfield,	13	2	15	11.32	-
Whitman,	4	2	6	12.26	-
Woburn,	19	12	31	10.08	8
Summary,	178	255	433	5.60	61

Summary of Milk Statistics.

	Number above Standard.	Number below Standard.	Total Samples collected.	Total Solids in Lowest Sample (Per Cent.).	Number of Skimmed Samples.	Number of Samples colored with Annatto.	Number of Samples preserved with Formaldehyde.	Number of Samples which contained Added Water.
Cities,	1,367	631	1,998	2.87	10	5	2	45
Towns,	1,164	256	1,420	8.23	12	-	-	27
Suspected producers,	178	255	433	5.60	-	-	-	61
Miscellaneous,	55	28	83	10.40	-	-	-	-
Totals,	2,764	1,170	3,934	2.87	22	5	2	133

Milk containing Added Water or Foreign Substances.

Dealer.	Locality.	Total Solids (Per Cent.).	Fat (Per Cent.).	Solids not Fat (Per Cent.).	Refraction of Serum at 20° C.	Foreign Substances.
Nellie F. Luce,	Melrose,	11.69	3.80	7.89	39.0	
William Leach,	North Gardner,	10.77	3.00	7.77	38.6	
Arthur G. Boynton,	Lowell,	11.00	3.05	7.95	38.6	
A. M. Robinson Company,	North Andover,	9.86	2.95	6.91	37.1	
Benjamin E. Harris,	Gloucester,	10.36	4.00	6.36	34.7	
George Dufton,	Andover,	10.70	3.50	7.20	37.5	
		9.44	3.00	6.44	36.1	
Alexander Mura,	Andover,	8.92	2.65	6.27	34.6	
		11.48	3.40	8.08	40.7	
		9.37	3.20	6.17	34.5	
		9.00	2.70	6.30	34.6	
Antonio Tavolieri,	Sudbury,	11.38	3.50	7.88	39.4	
		11.15	3.20	7.95	39.3	
		11.00	3.40	7.60	38.7	
Louis Sarra,	West Springfield,	11.12	3.20	7.92	39.2	
Charles H. Freeman,	Norton,	10.96	3.50	7.46	38.3	
Murray Bowen,	Rehoboth,	10.63	3.40	7.23	37.0	
Joseph Guimond,	Attleborough,	11.17	3.60	7.57	37.8	
John J. Welch,	Rehoboth,	11.17	3.65	7.52	38.8	
		11.24	3.75	7.49	38.6	
		11.46	3.80	7.66	38.9	
		10.94	3.75	7.19	37.7	
		11.34	3.80	7.54	38.7	
		10.50	3.50	7.00	37.1	
Cosmo Salene,	Dedham,	10.00	2.70	7.30	38.1	
Joseph S. Friend,	Medford,	10.59	3.20	7.39	37.5	
Martin E. Egan,	Pittsfield,	11.31	3.75	7.56	38.5	
Edward C. Wright,	Chelmsford,	9.76	2.80	6.96	37.4	
John Marinel,	Chelmsford,	10.84	3.25	7.59	39.3	
		8.63	1.35	7.28	38.0	
George W. Pierce,	Danvers,	9.52	2.70	6.82	36.1	
		9.60	2.65	6.95	36.8	
Streeter & Bailey,	Winchendon,	8.23	2.45	5.78	31.8	
George W. Smith,	Wakefield,	10.08	2.65	7.43	37.7	
		10.88	3.25	7.63	38.2	
Eldon Meekins,	Stoneham,	8.27	2.60	5.67	31.5	
		10.70	2.80	7.90	30.3	
		9.44	2.80	6.64	35.5	
		10.40	2.70	7.70	37.9	
Anthony Rogers,	- -	10.48	2.95	6.53	38.1	
		10.53	3.15	7.38	37.9	
Albert E. Kenneson,	Woburn,	11.05	2.90	8.15	38.8	
		11.00	2.90	8.10	38.8	
		10.08	2.65	7.43	36.9	
David T. Ray,	Haverhill,	8.60	2.50	6.10	34.7	
Amos C. Towle,	Saugus,	11.34	3.80	7.54	38.2	
Otis C. Haven,	Burlington,	3.60	1.80	3.80	27.1	
		8.40	2.90	5.50	31.0	
		8.32	2.60	5.72	31.5	
		9.32	3.30	6.04	32.5	
		6.70	2.35	4.35	28.7	
		9.00	2.80	6.20	33.8	
		11.58	3.25	8.33	38.9	
Sarkes Davragin,	Methuen,	10.60	3.20	7.40	38.9	
William H. Evans,	Rockport,	9.49	2.75	6.74	36.3	
Edward C. Burnett,	Lynn,	8.08	2.60	5.48	32.9	
Joseph McLaughlin,	Lynn,	10.00	3.80	6.20	34.0	
John Foster,	Lynn,	8.72	2.00	6.72	35.7	
Rawdon Macnamara,	Lynn,	8.50	3.15	5.35	32.4	
William H. McCarthy,	Lynn,	10.00	3.80	6.20	34.0	
		2.87	0.65	2.22	22.2	
Howard R. LeFavour,	Beverly,	11.80	2.85	8.95	-	Formaldehyde.
William E. Daley,	Braintree,	10.80	3.30	7.50	38.0	
Biel Anastas,	Tyngsborough,	10.81	3.20	7.61	37.9	
		10.80	3.20	7.60	37.8	
		10.09	3.10	6.99	36.5	
		10.24	3.00	7.24	36.8	
		10.80	3.20	7.60	37.4	
		10.28	3.20	7.08	36.5	

Milk containing Added Water or Foreign Substances — Concluded.

Dealer.	Locality.	Total Solids (Per Cent.).	Fat (Per Cent.).	Solids not Fat (Per Cent.).	Refraction of Serum at 20° C.	Foreign Substances.
Biel Anastas,	Tyngsborough,	10.80	3.20	7.60	37.6	
		10.21	3.20	7.01	36.8	
		10.21	3.20	7.01	38.0	
		10.49	3.20	7.29	37.8	
		10.50	3.20	7.30	37.8	
		10.40	3.10	7.30	37.7	
		10.80	3.20	7.60	36.6	
		10.92	3.40	7.52	37.3	
		11.18	3.60	7.58	37.3	
		11.18	3.60	7.58	37.3	
Patrick Rooney,	Bedford,	10.49	2.90	7.59	38.5	
		11.08	3.20	7.88	39.1	
		10.68	2.95	7.61	39.1	
George P. Beckford,	Plymouth	10.00	3.00	7.00	36.5	
Joseph M. Oliver,	Bedford,	7.69	2.00	5.69	33.1	
		7.44	2.00	5.44	32.3	
		7.60	2.00	5.60	32.6	
		8.21	2.20	6.01	33.8	
		8.20	2.60	5.60	-	
		7.80	2.40	5.40	-	
Michael McDevitt,	Woburn,	10.23	3.00	7.23	37.4	
		11.36	4.40	6.96	37.3	
		11.00	3.30	7.70	39.4	
		9.02	2.40	6.62	36.7	
		9.08	2.10	6.98	36.5	
		11.10	3.60	7.50	38.6	
		11.35	3.90	7.45	38.7	
		11.37	4.00	7.37	-	
Thomas E. Kenney,	Longmeadow,	11.63	3.85	7.78	39.0	
Nellie Burns,	Saugus,	12.60	4.00	8.60	-	Annatto.
		11.80	3.40	8.40	-	Annatto.
		11.74	3.40	8.34	39.6	Annatto.
		11.08	3.30	7.78	38.5	Annatto.
		11.22	3.40	7.82	39.1	
Thaddeus Fowler,	Agawam,	10.90	3.30	7.60	38.5	
		9.62	2.50	7.12	36.9	
		10.52	3.00	7.52	38.0	
		10.00	2.60	7.40	38.0	
		10.58	3.00	7.58	38.2	
Maynard C. Lewis,	Attleborough,	11.55	3.80	7.75	38.0	
Hans J. Schmidt,	Lynn,	10.48	3.30	7.18	37.5	
Frank N. Besson,	Swampscott,	11.74	3.60	8.14	-	Formaldehyde.
Samuel Gerrish,	Lynn,	10.85	3.30	7.55	38.0	
Ernest Harnish,	Methuen,	10.40	2.75	7.65	38.0	
		11.32	3.85	7.47	39.0	
William Burke,	East Bridgewater,	11.74	3.80	7.94	39.0	
		11.27	3.70	7.57	38.4	
Andrew T. Monahan,	Montello,	11.00	3.55	7.45	39.0	
Albert S. Forbush,	South Braintree,	9.56	2.45	7.11	36.7	
Edward P. Reynolds,	Methuen,	10.36	3.50	6.86	36.1	
		10.36	3.40	6.96	36.1	
		10.34	3.40	6.94	37.0	
		10.34	3.20	7.14	37.0	
William Horgan,	Salem,	11.36	3.40	7.96	38.5	
		11.36	3.20	8.16	38.9	

Milk from which a Portion of the Fat had been removed.

Dealer.	Locality.	Total Solids (Per Cent.).	Fat (Per Cent.).	Solids not Fat (Per Cent.).	Total Proteids (Per Cent.).
P. C. Veazie,	Chelsea,	11.65	2.70	8.95	-
		11.60	2.70	8.90	-
		11.84	2.90	8.94	-
		11.84	2.90	8.94	-
		11.34	2.40	8.94	-
		10.64	2.00	8.64	-
Albert E. Kenneson,	Woburn,	11.34	2.40	8.94	3.41
		12.26	3.20	9.06	3.38
		12.60	3.40	9.20	3.52
		12.40	3.20	9.20	3.45
		11.96	2.70	9.26	3.46
		12.14	3.00	9.14	3.30
John T. Ahlman,	Waltham,	11.30	2.60	8.70	3.29
Michael Beauregard,	West Springfield,	11.68	2.20	9.48	-
Patrick F. Quinn,	Lowell,	10.58	2.00	8.58	-
George O. Goodrich,	Melrose,	11.62	2.60	8.02	-
Albert A. Pollard,	Harvard,	10.62	2.45	8.17	-
		10.80	2.50	8.30	-
Elijah Hodoian,	Malden,	10.88	2.40	8.48	-
Samuel Schwab,	Chelsea,	10.80	2.30	8.50	-
Arthur St. Laruent,	Fall River,	11.20	2.20	9.00	-
Edwin C. Pool,	Rockport,	10.82	2.10	8.72	-
Harry Barbarial,	Cambridge,	10.42	2.15	8.27	-
Herbert E. Brier,	Saugus,	10.02	1.80	8.22	-
John Walkey,	Saugus,	10.72	2.20	8.52	-
William J. Biggerstaff,	Billerica,	11.18	2.60	8.58	-
		10.90	2.40	8.50	-
		11.10	2.60	8.50	-
		11.26	2.80	8.46	-

A large number of samples of milk of known purity have been examined during the year and these, together with those mentioned in the 1907 report, are included in the following tables.

The methods of analysis are those reported in past years and need no comment, the acetic acid method being used in the preparation of the

milk serum. All the cows were milked in the presence of an inspector or analyst of this department. A large number of samples were obtained from grade Holstein cows, and the high quality of the milk from these cattle is remarkable, considering the low quality of the milk obtained from Holstein cows; in fact, the grade Holstein cows seem to give milk very nearly as good as the grade cows of other breeds. The milk from the Jersey cows is of the highest quality of any of the milk examined, while that from the Guernsey cows comes next. The Holstein cows give the lowest quality milk of any of the breeds examined, and the Dutch Belt cows give but little better milk.

The claim has been made that the milk of Holstein cows differs from milk from other breeds only by its low fat content. The summary of analyses of milk of known purity will show that this is not the case. With a lowering of the solids and the fat there is also a diminution in the solids not fat and proteids, Holstein cows giving milk the lowest in proteids as well as the lowest in solids. It will also be noticed that the one constituent of milk showing the least variation is the milk sugar. This accounts for the fact that the refraction of the serum shows so little variation. There are also reported 15 samples of mixed milk of known purity. These samples varied from 14.57 to 11.96 per cent. of total solids. The character of the herds are as follows: —

1, Jersey; 2, Guernsey; 3 and 4, Jersey; 5, grade Holstein, grade Ayrshire, grade Jersey and grade Durham; 6, Guernsey and grade Guernsey; 7, Swiss, grade Ayrshire, grade Holstein and grade Jersey; 8, grade Holstein, grade Ayrshire and grade Jersey; 9, Ayrshire; 10, Ayrshire, grade Ayrshire and grade Jersey; 11, Dutch Belt; 12, grade Holstein, grade Durham, grade Ayrshire, grade Guernsey and grade Jersey; 13, grade Holstein, grade Hereford and grade Jersey; 14, Dutch Belt; 15, Holstein and grade Holstein.

Mixed Milk of Known Purity.

Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
1.034	14.57	5.40	3.54	0.78	9.17	4.85	44.1
1.034	14.40	5.00	3.77	0.77	9.40	4.86	44.6
1.033	14.20	5.00	3.61	0.79	9.20	4.80	-
1.033	14.08	4.80	3.58	0.78	9.28	4.92	-
1.033	13.35	4.00	3.50	0.75	9.35	5.10	43.3
1.031	13.08	4.75	2.65	0.68	8.33	5.00	42.2
1.031	12.95	4.00	3.09	0.68	8.95	5.10	42.0
1.033	12.76	4.40	3.20	0.77	8.36	4.35	41.8
1.033	12.57	4.00	2.90	0.77	8.57	4.90	43.1
1.032	12.56	4.20	2.83	0.73	8.36	4.80	43.1
1.031	12.55	3.65	3.43	0.67	8.90	4.80	43.4
1.032	12.49	3.65	3.45	0.74	8.84	4.65	43.0
1.033	12.22	3.50	3.08	0.80	8.72	4.84	42.1
1.032	12.03	3.60	2.62	0.68	8.43	5.00	42.6
1.032	11.96	3.35	2.99	0.69	8.61	4.89	42.2

Milk of Known Purity from Jersey Cows.

Age (Years).	Time since Calving (Months).	Weight of Milk (Pounds).	Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
2	5	6	1.033	17.17	7.70	3.65	0.72	9.42	5.05	45.2
-	7	11	1.032	16.60	6.80	3.25	0.75	9.80	5.80	43.7
-	2	12	1.033	16.33	6.70	4.30	0.68	9.63	4.65	-
5	3	20	1.033	16.00	7.20	2.79	0.81	8.80	5.20	45.2
-	2	12	1.032	16.00	6.80	3.88	0.72	9.20	4.60	44.6
7	6	8	1.034	15.56	6.10	3.81	0.80	9.46	4.85	43.9
5	7	10	1.035	15.52	6.20	3.36	0.81	9.32	5.15	44.7
-	1	14	1.031	15.30	6.60	3.47	0.84	8.70	4.35	-
2	5	8	1.034	15.21	5.60	4.09	0.72	9.61	4.80	44.1
7	7	8	1.033	15.12	6.00	3.33	0.69	9.12	5.10	45.0
8	3	8	1.033	15.10	6.00	3.33	0.77	9.10	5.00	44.8
3	6	8	1.032	14.66	6.30	3.06	0.80	8.36	4.50	43.7
-	3	8	1.033	14.60	5.80	3.59	0.70	8.80	4.50	-
7	6	6	1.034	14.56	5.00	3.58	0.83	9.56	5.15	44.7
4	4	12	1.033	14.34	5.00	3.79	0.75	9.34	4.80	44.2
7	6	8	1.033	14.15	5.10	3.47	0.78	9.05	4.80	44.0
7	6	8	1.033	14.10	5.40	2.99	0.76	8.40	4.95	43.9
-	4	12	1.033	13.41	4.80	3.57	0.74	8.61	4.30	-
-	3	11	1.032	13.56	4.65	3.57	0.64	8.91	4.70	43.2

Milk of Known Purity from Guernsey Cows.

5	12	4	1.035	17.00	6.35	4.93	0.80	10.65	4.92	45.4
5	8	8	1.034	16.33	6.40	4.63	0.82	9.93	4.48	43.0
5	8	5	1.035	15.83	5.95	4.06	0.77	8.88	5.05	44.4
10	15	5	1.035	15.80	5.75	4.24	0.73	10.05	4.98	45.0
7	8	4	1.034	15.66	5.80	3.99	0.77	9.86	5.10	43.5
17	15	3	1.034	15.56	5.60	4.58	0.79	9.95	4.58	42.8
5	4	8	1.034	15.50	6.20	3.60	0.71	9.30	4.99	44.2
4	8	7	1.034	15.35	5.70	3.72	0.71	9.65	5.22	44.5
10	17	8	1.034	14.90	5.30	4.03	0.76	9.60	4.81	44.6
3	6	7	1.033	14.40	5.20	3.68	0.72	9.20	4.88	44.9
4	6	9	1.033	14.32	5.00	3.77	0.75	9.32	4.80	44.0
4	14	8	1.032	14.14	5.20	3.43	0.72	8.98	4.80	44.3
5	8	4	1.034	13.99	4.60	3.66	0.70	9.39	5.03	45.1
6	15	5	1.031	13.26	4.65	3.53	0.73	8.61	4.75	43.6
4	1	12	1.033	13.08	4.25	2.96	0.73	8.83	5.14	44.9
7	14	7	1.032	12.92	4.00	3.61	0.70	8.92	4.61	42.8
8	1	12	1.032	12.52	4.35	2.65	0.77	8.14	4.75	43.1
4	7	11	1.032	12.23	3.80	2.98	0.75	8.43	4.70	43.0
8	11	8	1.031	12.15	4.15	2.26	0.69	8.00	5.05	41.5

Milk of Known Purity from Grade Ayrshire Cows.

Age (Years).	Time since Calving (Months).	Weight of Milk (Pounds).	Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
-	2	13	1.032	15.32	6.00	3.94	0.78	9.32	4.65	44.2
-	2	16	1.031	14.00	5.10	3.60	0.70	8.90	4.60	43.4
-	-	9	1.032	13.80	5.00	2.90	0.80	8.80	5.10	44.0
-	-	8	1.032	13.70	4.80	3.55	0.80	8.90	4.55	42.6
5	2	14	1.033	13.54	4.55	3.39	0.74	8.99	4.86	43.3
8	10	4	1.031	13.36	4.60	3.13	0.72	8.76	4.91	41.8
4	6	8	1.032	13.32	4.35	3.07	0.69	8.97	5.21	41.7
-	-	13	1.031	13.22	4.80	2.85	0.77	8.42	4.80	42.8
-	-	9	1.032	13.18	4.80	2.75	0.83	8.38	4.75	41.6
-	-	6	1.032	13.08	4.60	2.88	0.75	8.48	4.85	44.0
-	-	11	1.032	13.04	4.60	3.27	0.82	8.44	4.35	43.1
13	8	-	1.031	13.08	4.00	3.48	0.75	9.08	4.85	42.0
9	5	12	1.033	12.90	4.10	3.22	0.73	8.80	4.87	43.7
6	2	-	1.032	12.86	4.00	3.30	0.68	8.86	4.85	43.8
-	-	14	1.030	12.36	4.60	2.11	0.85	8.76	4.80	42.0
7	2	16	1.030	11.78	3.80	2.44	0.77	7.98	4.74	40.7

Milk of Known Purity from Grade Durham Cows.

Weight of Milk (Pounds).	Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
14	1.033	15.28	6.25	3.35	0.60	9.03	5.08	44.0
10	1.032	14.32	5.60	3.23	0.68	8.72	4.81	43.3
10	1.032	14.20	5.00	3.39	0.75	9.20	5.07	43.8
13	1.033	14.07	5.05	3.50	0.75	9.02	4.77	42.6
9	1.034	14.06	4.70	3.75	0.71	9.36	4.91	44.3
15	1.033	14.00	5.15	3.00	0.69	8.85	4.81	43.3
16	1.032	13.48	4.80	3.08	0.69	9.08	4.91	42.8
15	1.032	13.46	5.00	2.90	0.72	8.46	4.84	43.4
14	1.032	13.33	4.90	2.96	0.69	8.43	4.78	43.0
10	1.033	13.00	4.20	3.38	0.72	8.80	4.70	42.7
10	1.032	12.88	4.20	3.21	0.73	8.68	4.73	43.6
13	1.031	12.80	4.35	2.89	0.68	8.45	4.88	42.7
12	1.033	12.00	3.80	2.84	0.77	8.20	4.59	41.1

Milk of Known Purity from Grade Jersey Cows.

Age (Years).	Time since Calving (Months).	Weight of Milk (Pounds).	Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
-	-	8	1.032	14.00	5.40	3.08	0.70	8.60	4.85	43.4
4	6	-	1.031	13.98	4.85	3.70	0.73	9.13	4.70	42.4
3	7	5	1.031	13.98	4.80	3.46	0.70	9.18	5.02	42.1
-	2	10	1.032	13.66	4.70	3.45	0.70	8.96	4.81	42.8
6	4	6	1.034	13.59	4.35	3.30	0.75	9.24	5.19	42.7
9	4	14	1.030	13.35	4.50	3.44	0.76	8.85	4.65	43.1
10	9	8	1.032	12.96	4.55	3.30	0.76	8.41	4.35	41.3
10	9	7	1.032	12.90	4.20	3.27	0.74	8.70	4.69	42.0
9	2	14	1.033	12.80	3.85	3.10	0.72	8.95	5.13	43.3
-	7	-	1.031	12.10	3.40	3.00	0.70	8.70	5.00	42.6

Milk of Known Purity from Grade Guernsey Cows.

Age (Years).	Time since Calving (Months).	Weight of Milk (Pounds).	Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
7	1	13	1.034	14.74	5.20	3.94	0.78	9.54	5.00	45.0
8	8	12	1.031	13.22	4.80	2.88	0.66	8.42	5.10	43.9
9	7	14	1.032	13.14	4.60	2.99	0.77	8.54	4.90	43.0
-	-	13	1.031	13.08	4.05	3.33	0.70	9.03	5.00	44.9
8	1	11	1.035	13.03	3.80	3.66	0.74	9.28	5.05	44.5
-	-	8	1.032	12.92	4.60	2.77	0.75	8.32	4.80	43.0
7	9	6	1.033	12.88	4.00	3.35	0.76	8.88	4.77	43.0
8	2	12	1.032	12.73	4.40	3.11	0.78	8.33	4.85	43.7
7	7	10	1.032	12.56	4.10	2.98	0.68	8.46	5.05	43.3
9	3	13	1.031	12.56	4.05	3.13	0.76	8.51	4.62	43.0
8	8	10	1.032	12.60	4.00	2.97	0.75	8.60	5.15	44.2
8	8	13	1.032	11.82	3.80	2.42	0.69	8.02	4.90	43.6

Milk of Known Purity from Grade Holstein Cows.

Age (Years).	Time since Calving (Months).	Weight of Milk (Pounds).	Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
3	8	10	1.034	15.33	5.95	3.93	0.68	9.34	4.82	43.8
5	7	8	1.034	14.51	4.90	3.81	0.74	9.61	5.09	43.7
5	7	7	1.032	14.24	4.90	3.81	0.72	9.34	4.81	43.4
4	11	-	1.034	14.05	4.50	3.80	0.75	9.55	5.00	41.2
-	-	10	1.031	13.65	4.60	3.45	0.60	9.05	5.00	44.2
7	4	10	1.031	13.40	4.35	3.12	0.74	9.05	5.19	42.2
6	3	-	1.033	13.36	4.20	3.84	0.72	9.16	4.60	43.7
6	2	-	1.033	13.29	4.00	3.61	0.68	9.29	5.00	45.6
2	1	10	1.033	12.77	3.60	3.12	0.78	8.67	4.77	42.5
4	2	14	1.031	12.40	3.60	3.06	0.70	8.80	4.84	41.5
11	4	8	1.030	12.18	3.70	3.25	0.73	8.48	4.50	42.3
2	1	9	1.034	12.12	3.30	3.06	0.77	8.82	5.00	43.9
8	8	14	1.030	12.04	3.70	3.36	0.76	8.34	4.22	41.4
4	9	10	1.031	11.84	3.20	3.17	0.70	8.64	4.77	42.5
7	1	17	1.032	11.83	3.10	3.05	0.68	8.73	5.05	42.3
7	5	10	1.032	11.82	3.60	2.76	0.70	8.22	4.86	41.3
7	5	12	1.033	11.75	3.75	2.73	0.68	8.00	4.59	41.2
9	4	14	1.031	11.72	3.40	2.92	0.68	8.32	4.72	42.0
-	-	14	1.030	11.00	3.15	2.74	0.71	7.85	4.40	42.7
12	1	17	1.030	10.92	3.00	2.92	0.73	7.92	4.27	40.0

Milk of Known Purity from Ayrshire Cows.

Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
1.032	14.68	5.40	2.64	0.71	9.28	5.00	42.2
1.031	13.14	4.10	3.56	0.68	9.04	4.80	43.4
1.033	12.90	4.10	3.22	0.73	8.80	4.87	43.5
1.032	12.80	4.00	3.10	0.70	8.80	5.00	42.4
1.031	12.58	3.80	3.31	0.67	8.78	4.80	42.7
1.031	12.14	3.30	2.84	0.70	8.84	5.30	43.0
1.030	12.04	3.40	3.02	0.58	8.64	5.00	42.5
1.032	11.84	3.50	2.64	0.70	8.34	5.00	42.2
1.031	11.80	3.50	2.75	0.65	8.30	4.90	42.5
1.031	11.75	3.20	2.95	0.60	8.55	5.00	43.0
1.031	11.65	3.30	2.55	0.70	8.35	5.10	42.8
1.030	11.44	3.55	2.21	0.68	7.89	5.00	41.5
1.031	11.24	3.22	2.91	0.61	8.04	4.50	42.3

Milk of Known Purity from Dutch Belt Cows.

1.033	14.09	4.75	3.47	0.70	9.34	4.85	44.4
1.033	13.78	4.35	3.50	0.76	9.43	5.17	43.8
1.032	13.01	3.80	3.61	0.75	9.21	4.85	42.5
1.034	12.94	3.80	3.13	0.76	9.14	5.35	44.4
1.034	12.82	3.60	3.10	0.73	9.22	4.90	44.5
1.033	12.46	3.50	3.09	0.66	8.96	4.75	43.2
1.031	12.43	3.90	2.97	0.70	8.33	4.86	42.6
1.032	12.32	3.70	2.76	0.72	8.62	5.10	43.5
1.032	11.98	3.50	2.58	0.66	8.48	5.10	43.0
1.032	11.96	3.50	2.76	0.70	8.46	4.90	43.0
1.030	11.84	3.40	2.79	0.71	8.44	4.75	42.3
1.032	11.80	3.40	2.58	0.70	8.40	5.00	42.8
1.031	11.78	3.60	2.74	0.66	8.18	4.65	41.7
1.031	11.77	3.40	2.97	0.70	8.37	4.70	42.2
1.030	11.65	3.45	2.60	0.70	8.20	4.90	41.7
1.030	11.63	3.60	2.55	0.68	8.03	4.80	42.3
1.031	11.62	3.60	2.74	0.70	8.02	5.06	42.4
1.030	11.58	3.60	2.55	0.63	7.98	4.80	42.3
1.031	11.44	3.40	2.60	0.72	8.08	4.90	42.0
1.031	11.38	3.35	2.70	0.75	8.03	4.58	42.9
1.031	11.28	3.00	2.46	0.69	8.28	5.06	43.0
1.030	11.05	3.20	2.67	0.74	7.65	4.50	41.0
1.030	11.01	3.20	2.34	0.65	8.81	4.83	41.0
1.030	10.93	3.20	2.83	0.70	7.73	4.20	41.4

Milk of Known Purity from Holstein Cows.

Age (Years).	Time since Calving (Months).	Weight of Milk (Pounds).	Specific Gravity, 15°.	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Ash (Per Cent.).	Solids not Fat (Per Cent.).	Milk Sugar (Per Cent.).	Refraction of Serum at 20° C.
3	½	20	1.034	13.96	4.35	4.03	0.76	9.61	4.82	42.9
5	8	8	1.033	13.04	3.50	3.40	0.73	8.64	4.47	43.0
2	9	8	1.032	12.08	3.20	3.19	0.73	8.88	5.16	43.2
4	7	6	1.032	12.00	3.30	3.22	0.73	8.70	4.78	41.1
2	6	10	1.031	11.87	3.30	3.25	0.70	8.57	4.87	42.6
10	9	11	1.030	11.80	3.20	3.03	0.75	8.60	4.87	40.4
4	6	11	1.032	11.58	3.30	2.81	0.70	8.28	4.77	42.3
4	6	6	1.031	11.52	3.40	3.38	0.72	8.12	4.02	39.9
4	2	16	1.031	11.31	3.15	2.73	0.75	8.16	4.68	41.8
4	7	10	1.030	11.26	3.00	2.89	0.68	8.26	4.69	41.0
5	½	17	1.031	10.95	2.90	2.63	0.73	8.05	4.89	41.8
10	1	-	1.032	10.86	2.70	2.52	0.54	8.16	5.10	43.0
6	½	24	1.032	10.78	2.80	2.66	0.74	7.98	4.58	40.4
		29	1.030	10.62	2.55	2.42	0.75	8.07	4.90	40.4
3	15	9	1.030	10.65	2.75	2.70	0.67	7.90	4.53	40.0
7	½	15	1.031	10.40	2.75	2.70	0.76	7.65	4.19	40.3

Summary of Analysis of Milk of Known Purity.

	Jersey.	Guernsey.	Grade Ayrshire.	Grade Durham.	Grade Jersey.	Grade Guernsey.	Grade Holstein.	Ayrshire.	Dutch Belt.	Holstein.	Mixed Milk.
Number of samples,	19	19	16	13	10	12	20	13	24	16	15
Total solids (per cent.):—											
Highest,	17.17	17.00	15.32	15.28	14.00	14.74	15.38	14.68	14.09	13.96	14.57
Lowest,	13.41	12.15	11.78	12.00	12.10	11.82	10.92	11.24	10.93	10.40	11.96
Average,	15.12	14.46	13.28	13.60	13.83	12.97	12.71	12.31	12.02	11.49	13.05
Fat (per cent.):—											
Highest,	7.70	6.40	6.00	6.25	5.40	5.20	5.95	5.40	4.75	4.35	5.40
Lowest,	4.65	3.80	3.80	3.80	3.40	3.80	3.00	3.22	3.00	2.55	3.35
Average,	5.98	5.18	4.61	4.86	4.46	4.28	3.92	3.72	3.58	3.11	4.22
Proteids (per cent.):—											
Highest,	4.30	4.93	3.94	3.75	3.70	3.94	3.93	3.56	3.61	4.03	3.61
Lowest,	2.79	2.26	2.11	2.84	3.00	2.43	2.73	2.21	2.34	2.42	2.62
Average,	3.52	3.70	3.12	3.18	3.30	3.13	3.27	2.87	2.83	2.96	3.22
Solids not fat (per cent.):—											
Highest,	9.80	10.65	9.32	9.36	9.24	9.54	9.34	9.28	9.43	9.61	9.40
Lowest,	8.36	8.00	7.98	8.20	8.41	8.02	7.85	7.89	7.65	7.65	8.33
Average,	9.24	9.28	8.67	8.74	8.87	8.69	8.79	8.59	8.44	8.37	8.83
Milk sugar (per cent.):—											
Highest,	5.80	5.22	5.21	5.08	5.19	5.15	5.19	5.30	5.35	5.16	5.18
Lowest,	4.30	4.48	4.35	4.59	4.35	4.62	4.22	4.50	4.20	4.02	4.35
Average,	4.85	4.87	4.78	4.84	4.84	4.93	4.77	4.94	4.85	4.76	4.83
Refraction of serum at 20° C:—											
Highest,	45.2	45.4	44.2	44.3	43.4	45.0	45.6	43.5	44.4	43.0	44.6
Lowest,	43.2	41.5	40.7	41.1	41.3	42.6	40.0	41.5	41.0	39.9	41.8
Average,	44.3	44.1	42.8	42.9	42.6	43.7	42.5	43.1	42.6	41.4	42.8

During the year we have found rather common the practice of mixing skimmed milk with whole milk, or of partially skimming the night's milk, by certain of the suspected producers. To detect this form of adulteration it is necessary to make nitrogen and fat determinations upon the milk. The most important work upon relation between fat and proteids is that of Van Slyke.[1]

His conclusions are drawn from the following data: 300 analyses of the mixed milk of numerous herds obtained at cheese factories, such as is common in the dairy regions of New York State; 650 analyses of milk of 50 separate herds, covering a period of about six months; and several thousand analyses of milk of individual cows, representing 7 different breeds. He has found the relation of fat to protein for the different breeds to be as follows: —

Holstein-Friesian,	1:0.87
Ayrshire,	1:0.82
American Holderness,	1:0.83
Shorthorn,	1:0.80
Devon,	1:0.80
Guernsey,	1:0.66
Jersey,	1:0.64

We have made a large number of analyses of protein and fat in milk and the figures we have obtained are in accordance with the ratios given by Van Slyke. It is evident, from these figures, that the milk has been skimmed if the proteids are higher than the fat. The following analyses show the composition of samples of milk obtained from a milk dealer who was subsequently convicted of selling milk from which a portion of the fat had been removed: —

Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).	Total Solids (Per Cent.).	Fat (Per Cent.).	Proteids (Per Cent.).
11.34	2.40	3.41	12.40	3.20	3.45
12.26	3.20	3.38	11.96	2.70	3.46
12.60	3.40	3.52	12.14	3.00	3.30

Assuming an average ratio of fat to proteids of 1:0.8, the above analyses show that the first sample reported probably consisted of a mixture of 40 per cent. skimmed milk with 60 per cent. whole milk, the second sample contained 24 per cent. skimmed milk, the third sample 22 per cent. skimmed milk, the fourth sample 25 per cent. skimmed milk,

[1] Jour. Am. Chem. Soc., 30, 1166–1186.

the fifth sample 37 per cent. skimmed milk, and the sixth sample 27 per cent. skimmed milk. A sample of milk obtained from another dealer had the following composition: total solids, 11.30 per cent.; fat, 2.60 per cent.; proteids, 3.29 per cent. This corresponds to a mixture of 36 per cent. skimmed milk with 64 per cent. whole milk.

During the past two years considerable work has been done upon the different methods of preparing milk serum for the purpose of ascertaining if a better method than the acetic acid method, employed by this department, could be obtained. The methods studied were the acetic acid method,[1] the natural souring method,[2] the calcium chloride method,[3] and the asaprol method.[4] The details of the methods are as follows:[5]

Acetic Acid Method. — To 100 cubic centimeters of milk at about 20°C. add 2 cubic centimeters of 25 per cent. acetic acid, mix well and place in a water bath at 70°C. for twenty minutes. Cool ten minutes in ice water and filter.

Calcium Chloride Method. — The details have been slightly modified from the method of Ackermann, described above. Place 90 cubic centimeters of milk in a flask, add 0.75 cubic centimeters of calcium chloride solution, specific gravity 1.1375 (when diluted 1:10 this solution reads 26 on the immersion refractometer at 17.6°C.), shake thoroughly; close the flask with a cork carrying a glass tube to act as a reflux condenser, place in a boiling water bath for twenty minutes, cool to 20°, mix the condensed water and serum without shaking, and filter.

Asaprol Method. — The precipitating solution is made by dissolving 30 grams of asaprol and 55.8 grams of crystallized citric acid in 1 liter of water. If the refraction is not 36.3 at 20°C. on the scale of the immersion refractometer, add citric acid or water to make it so. Mix equal volumes of the above solution and the milk, shake well and filter.

Of the above methods, the asaprol method is the easiest of manipulation, gives the clearest serum in the least time and shows the lowest refraction with the least variation. Unfortunately, pure asaprol is very difficult to obtain, and, owing to the fact that it decomposes readily, it is not an easy matter to prepare different solutions that will give identical sera with the same sample of milk.

The calcium chloride method is the most difficult of manipulation and is liable to give a cloudy serum, rather troublesome to read, but the figures do not vary so much and are lower than those obtained by the acetic acid method. The natural souring method is too slow for ordinary use, but

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[1] Leach and Lythgoe, Jour. Am. Chem. Soc., 26, 1195.
[2] Matthes and Müller, Z. öffentl. Chem., 10, 173.
[3] Ackermann, Z. Nahr-Genussm, 13, 186.
[4] Baier and Neumann, Z. Nahr-Genussm, 13, 369.
[5] Lythgoe and Nurenberg, Jour. Ind. and Eng. Chem., 1, 38.

is valuable in the hot weather if the milk is nearly sour when it reaches the analyst. As a rule, the figures are lower than those obtained by the acetic acid method, but in a few cases they run higher.

The only objection found to the asaprol method was the difficulty in obtaining pure asaprol for the preparation of the precipitating solution. We have devised a method similar to the asaprol method, without its objections, which is as follows: the precipitating solution is prepared by dissolving 72.5 grams of crystallized copper sulphate in one liter of water. This solution will have a refraction of 36 at 20°C. on the scale of the Zeiss immersion refractometer. Mix 40 cubic centimeters of milk with 10 cubic centimeters of the above solution, shake thoroughly, allow to stand a few minutes and filter. If the filtrate come through cloudy, pour back upon the same filter, and it will then filter clear. The refraction of the clear filtrate is then obtained by means of the immersion refractometer. Pure milk has been found by this method to refract from 36.1 to 39, while by the acetic acid method the refractions have varied from 39.5 to 44. The following table shows the figures obtained by this method upon samples of pure milk: —

Refraction of Copper Sulphate Serum from Milk of Known Purity.

Total Solids (Per Cent.).	Refraction of Serum at 20° C.	Total Solids (Per Cent.).	Refraction of Serum at 20° C.	Total Solids (Per Cent.).	Refraction of Serum at 20° C.	Total Solids (Per Cent.).	Refraction of Serum at 20° C.	Total Solids (Per Cent.).	Refraction of Serum at 20° C.	Total Solids (Per Cent.).	Refraction of Serum at 20° C.
17.00	38.9	15.27	38.3	14.28	37.6	13.66	38.6	13.04	38.3	11.83	37.8
16.80	38.6	15.18	39.2	14.28	38.3	13.59	37.9	13.00	38.1	11.80	36.5
16.60	38.6	15.14	38.0	14.20	38.5	13.56	38.4	13.00	38.0	11.78	37.4
16.58	38.0	15.04	37.2	14.08	38.5	13.54	38.1	12.94	38.0	11.58	37.2
16.33	37.5	15.00	37.9	14.07	37.7	13.50	38.2	12.95	37.7	11.52	36.1
16.28	38.8	14.90	38.3	14.06	39.0	13.48	37.2	12.92	37.0	11.47	36.9
16.00	37.1	14.75	38.1	14.06	38.4	13.46	38.1	12.88	38.2	11.31	37.1
15.96	37.5	14.73	38.1	14.03	37.7	13.40	37.9	12.80	38.3	11.02	36.6
15.83	38.4	14.66	38.2	14.02	37.8	13.36	37.9	12.80	38.3	10.95	37.3
15.80	38.6	14.63	39.0	14.00	38.6	13.36	37.7	12.80	38.3	10.91	36.4
15.66	38.4	14.45	37.9	14.00	38.9	13.33	38.2	12.40	37.3	10.78	36.3
15.55	37.7	14.51	38.6	13.99	39.0	13.32	37.4	12.08	37.6	10.78	36.4
15.35	38.5	14.57	38.0	13.98	37.6	13.28	38.2	12.00	36.9	10.65	36.2
15.32	38.8	14.40	38.4	13.96	37.9	13.27	36.8	12.00	37.0	10.62	36.3
15.32	37.1	14.38	38.9	13.80	38.1	13.08	38.0	11.96	37.2	10.40	36.1
15.28	39.3	14.32	37.9	13.70	38.3	13.06	37.7	11.37	36.7		

CREAM.

One hundred and seventy samples of cream were examined, 60 of which were reported adulterated, by reason of the fact that they were found to contain calcium sucrate. The method used for the detection of these substances is that of Baier and Neumann.[1] Place 25 cubic centimeters of cream in a small Erlenmeyer flask, add 10 cubic centimeters of a 5 per cent. uranium acetate solution, shake, allow to stand about five minutes and filter; if the filtrate is not clear, pour back through the same filter. To the clear filtrate add 2 cubic centimeters of a cold, saturated solution of ammonium molybdate and 8 cubic centimeters of dilute hydrochloric acid (1 part 25 per cent. acid and 7 parts water), shake and place in a water bath at 80° C. for five minutes. In the presence of calcium sucrate, the solution will be of a deep Prussian blue color, while, if the sample is pure, it will be of a green color, resembling a nickel sulphate solution. Occasional samples of pure cream have been found to give a pale bluish color, but this will not be confounded with the color obtained from the adulterated sample. The chemists hired by the large cream dealers are of the opinion that this test is unreliable, on account of these pale blue colors obtained from pure samples, but, since the dealers have known of the existence of this test, we have been unable to obtain any cream upon the market which gives the proper color for adulterated cream. It has been claimed that tin salts, iron salts and hydrogen sulphide will give this reaction. It has also been claimed that cream that has been pasteurized and allowed to stand for several days will develop fermentation products which will give the blue color. We have never been able to get this test by mixing any of the above substances with pure cream, or by any modification of the pasteurizing process. This test is given by dextrose, and in order to distinguish between sucrose and dextrose a confirmatory test may be used by applying the resorcine test for cane sugar to the filtrate obtained from the cream treated with uranium acetate, as follows: to 5 cubic centimeters of the serum add 0.1 gram of resorcine and 0.5 cubic centimeters concentrated hydrochloric acid, heat for five minutes in a boiling water bath, and the characteristic red color will be produced in the presence of cane sugar.

In addition to the Baier and Neumann test for sugar, determinations of alkalinity of ash and calcium were made, the methods being as follows: weigh 25 grams of cream into a platinum dish, gently heat over a free flame until the fat has all burned and place in muffle at a low red heat until ashed. Dissolve the ash in 20 cubic centimeters of N/10

[1] Z. Nahr-Genussm, 16, 51-63.

sulphuric acid, wash into a flask, boil to remove carbon dioxide and then titrate with N/10 sodium hydroxide, using phenolphthalein as the indicator. Express results as cubic centimeters; N/10 acid required to neutralize the ash of 100 grams of cream. Make the residual solution from the above determination acid with acetic acid, add 1 gram of sodium acetate, heat to boiling and add an excess of a boiling ammonium oxalate solution, filter, and wash the precipitated calcium oxalate with hot water. Dissolve in hot dilute sulphuric acid and titrate hot with N/10 potassium permanganate. Multiply the number of cubic centimeters of N/10 permanganate by 0.0112, to obtain the percentage of CaO in the sample.

The following table shows the composition of pure and adulterated cream: —

Composition of Samples of Pure Cream.

Fat (Per Cent.).	Ash (Per Cent.).	Alkalinity of Ash.	CaO (Per Cent.).	Sucrose.	Fat (Per Cent.).	Ash (Per Cent.).	Alkalinity of Ash.	CaO (Per Cent.).	Sucrose.
45.2	0.36	7.6	0.073	None.	39.2	0.36	7.2	0.065	None.
43.2	0.35	6.0	0.073	None.	39.6	0.41	6.8	0.063	None.
42.8	0.39	6.4	0.062	None.	37.2	0.41	7.2	0.086	None.
41.4	0.43	8.8	0.099	None.	36.8	0.33	7.6	0.094	None.
41.4	0.37	6.8	0.069	None.	36.8	0.46	7.6	0.063	None.
40.4	0.38	7.6	0.092	None.	34.4	0.54	9.6	0.108	None.
39.2	0.40	8.0	0.091	None.					

Composition of Samples of Adulterated Cream.

Cubic Centimeters of Calcium Sucrate added per Liter.	Fat (Per Cent.).	Ash (Per Cent.).	Alkalinity of Ash.	CaO (Per Cent.).	Sucrose.
5	37.9	0.50	19.2	0.147	Present.
2	37.9	0.46	13.2	0.130	Present.
5	41.4	0.39	11.6	0.095	Present.
4	42.8	0.43	10.0	0.101	Present.
-	36.4	0.49	16.0	0.123	Present.

Condensed Milk.

The adulterated brands of condensed milk found during the year are as follows: Ontario and Manx brands, made by the Wayne County Condensed Milk Company, Ontario Center, N. Y., were found to contain 1.22 per cent. and 2.78 per cent. fat in the original milk, respectively. The Mayflower brand of condensed milk, made by the Vermont Condensed Milk Company, Richmond, Vt., was found to contain 2.50 per cent. fat

in the original milk. Gold Evaporated Milk, made by Hires Condensed Milk Company, was found to contain 2.5 per cent. fat in the original milk.

Food Exclusive of Milk.

The summary of analyses of food products may be found on page 603. Under the several headings only such facts as require special consideration will be discussed.

Butter.

Fifty-four samples of butter were examined during the year, of which 4 were adulterated. These consisted of 2 samples of renovated butter and 2 samples of oleomargarine.

Canned Fruits and Vegetables.

One sample, Libby's Premier Tomato Soup, was found adulterated with benzoic acid; the other 65 samples were found to be pure.

Celery Salt.

Of 11 samples examined, 6 were classed as adulterated, by reason of their containing a large amount of starch. The following are the samples adulterated, with the names of the manufacturer or wholesaler and the adulterant:—

A. Colburn Company, Philadelphia, Pa.,	Corn starch.
Sparhawk, Poole & Co., London, E. C.,	Corn starch.
Bennett, Simpson & Co., London, E. C.,	Wheat starch.
Cobb, Bates & Yerxa Company, Boston,	Corn starch.
The Horton-Cato Manufacturing Company, Detroit, Mich.,	Wheat starch.
Haskell Adams & Co., Boston,	Corn starch.

Cheese.

Twenty-two samples were examined, 7 of which were classed as adulterated. These samples contained a boron preservative and were made by the MacLaren Imperial Cheese Company, Detroit, Mich. The outside wrapper was labeled "absolutely pure", the jar was labeled "contains 1 per cent. borate". Samples containing preservatives are not regarded as pure under the law and should not be marked so, and, furthermore, the name of the antiseptic used should be stated upon the package.

Cider.

Seventy-eight samples were examined, 32 of which were classed as adulterated. These samples were largely purchased by the inspectors in stores and contained no label whatsoever. They were found to be

adulterated with salicylic or benzoic acid. Four samples in bottles, labeled with the name of the wholesaler or producer, were found adulterated. One sample of Chelmsford Spring Champagne Cider consisted largely of carbonated water and cane sugar. A sample of carbonated sweet cider, put up by Coleman & Keating, Boston, consisted of a carbonated cane sugar solution with about 5 per cent. of cider. One sample of Champagne Cider, from J. H. Faught, South Ackworth, N. H., was found preserved with benzoic acid, and a sample of Refined Apple Cider, put up by Con Keefe, Boston, was found preserved with salicylic acid.

Cocoa.

Six samples of cocoa were found to be adulterated. London Breakfast Cocoa, made by the Crown Chocolate Company of Chelsea, was found to contain 25 per cent. of wheat, and was not properly labeled. Fry's Caracas Cocoa, J. S. Fry & Sons, Limited, Bristol and London, contained a large mixture of sugar arrowroot. Sterry's Cocoa, made by Sterry & Sterry, New York, was found to consist entirely of cocoa shells.

Eggs.

Three samples of broken eggs were examined, all of which were found free from preservatives.

Flavoring Extracts.

Two samples of lemon extract, 2 of orange, 1 of raspberry, 1 of strawberry, 4 of vanilla and 2 of wintergreen were found to be of inferior quality. The brands of the inferior extracts are reported in the following table: —

List of Inferior Flavoring Extracts.

Character of Extract.	Brand, Manufacturer or Wholesaler.	Result of Analysis.
Lemon,	Superior Compound,	0.2 per cent. lemon oil.
Lemon,	Star Extract Company, Lynn, Mass.,	0.94 per cent. lemon oil.
Vanilla,	Forest City Extract Company, Portland, Me.,	Contained coumarin.
Vanilla,	Leighton's Pure, Portland, Me.,	Contained coumarin.
Orange,	Sterling Extract Company, Cambridge, Mass.,	Contained no orange oil.
Orange,	Geo. S. Hull & Co., Lowell, Mass.,	Contained 2.8 per cent. orange oil.
Checkerberry,	Gowing Extract Company, North Reading, Mass.,	Contained 0.8 per cent. wintergreen oil.
Raspberry,	Oliver Johnson & Co., Providence, R. I.,	Artificial.
Strawberry,	Oliver Johnson & Co., Providence, R. I.,	Artificial.

Grape Juice.

Twenty-five samples of grape juice were examined, of which 3 were adulterated. These 3 were the product of Adolph Prince Company, New

York. They were marked unfermented grape juice; 2 samples were preserved with salicylic acid and 1 sample contained 10.38 per cent. of alcohol and a trace of salicylic acid.

Jams, Jellies and Preserves.

Ninety-five samples were examined, of which 12 were found to contain preservatives. The following table gives the list of adulterated brands: —

Adulterated Brands of Preserved Fruits.

Character of Sample.	Manufacturer or Wholesaler.	Antiseptic Present.
Cherries,	Libby, McNeill & Libby, Chicago, Ill.,	Benzoic acid.
Bigarre aux Roses au Marasquin,	Mihalovitch, Fletcher & Co., Cincinnati, O.,	Sulphurous acid.
White Swan Maraschino Cherries.	Mihalovitch, Fletcher & Co., Cincinnati, O.,	Sulphurous acid.
Golden Star Maraschino Cherries.	Mihalovitch, Fletcher & Co., Cincinnati, O.,	Sulphurous acid.
Bigarre aux Marasquin,	Rheinstrom, Betterman, Johnson & Co., Cincinnati, O.	Sulphurous acid.
Bigarre aux Roses au Marasquin,	H. F. Laurent & Co.,	Sulphurous acid.
Preserved raspberries,	Dunklay Preserving Company, Kalamazoo, Mich.	Benzoic acid.
Red raspberries,	Dunklay Preserving Company, Kalamazoo, Mich.	Benzoic acid.
Strawberry preserves,	Twitchell, Champlin Company, Boston,	Benzoic acid.

Lard.

Five samples were examined, 1 of which contained cotton-seed oil.

Malt Liquor.

Three samples of ale, 4 of beer, 5 of porter and 1 of malt extract were examined, all of which were found free from preservatives.

Maple Products.

Forty-two samples of maple sugar were examined, 12 of which were found to be adulterated, as they contained considerable cane sugar. One sample of maple syrup was reported adulterated, and 19 samples were found to be pure, or to conform to the label upon the package.

Meat Products.

Twenty samples of canned meat were examined, of which 3 were adulterated. Lawson Pink devilled ham, put up by Roger I. Sherman Company, Boston; potted ham, Columbia Conserve Company, Indianapolis, Ind., and Libby's Vienna sausage were found to contain boron preservatives. Twenty-six samples of hamburg steak, out of 86 examined,

were preserved with sodium sulphite, and were not properly labeled according to law. Two samples of mince meat were adulterated with benzoic acid, and 2 samples of sausage, out of a total of 94, were found to contain boron preservatives. One sample of beef extract, 16 samples of head cheese, 2 of jellied meats, 7 of lamb's tongues, 1 of pig's feet, 10 of pressed beef and 2 of tripe were found to be free from preservatives.

Pickles.

Sixty-seven samples of pickles were examined, 4 of which were adulterated. The adulterated samples of pickles contained alum, and were obtained from Lutz & Schramm Company, Allegheny, Pa., and from Libby, McNeill & Libby, Chicago, Ill.

Proprietary Foods.

Fourteen samples were examined, 10 of which were adulterated, as they contained alcohol and were not marked according to the proprietary food and medicine law. The following were found to contain alcohol: —

Brand.	Manufacturer.	Result of Analysis.
Hire's Ginger Ale Extract, .	Chas. E. Hire's Company, Malvern and Philadelphia, Pa.	16.30 per cent.
Hire's Root Beer Extract, .	Chas. E. Hire's Company, Malvern and Philadelphia, Pa.	6.56 per cent.
Indian Root Beer Extract, .	Baker Extract Company, Springfield, Mass., .	10.64 per cent.
Dr. Swett's Root Beer Extract.	Dr. Swett's Root Beer Extract Company, Boston, Mass.	11.70 per cent.
Bryant's Root Beer Extract,	Michigan Drug Company, Detroit, Mich., . .	5.44 per cent.
Crescent Root Beer Extract,	Crescent Root Beer Extract Company, . . .	7.32 per cent.

Spices.

Forty samples of spices were examined, 1 sample was found adulterated. This sample was marked "Merrimac Pure White Pepper, F. M. Bill Company, Lowell," and contained about 25 per cent. of peas and wheat.

Syrup.

Nine samples were found pure and 1 sample was found adulterated. This sample was labeled "Feinster Himbeer Syrup, Berlin-Werdersche Früchteconserven-Fabrik Moral, Berlin, Ger.," and was found to contain .02 per cent. salicylic acid.

Table Sauce.

Fifty-three samples were examined, and 12 samples were found to contain preservatives, and were not labeled according to the law. The following table gives the brands of adulterated samples:—

Brand.	Manufacturer.	Antiseptic Present.
"Wild Rose" ketchup,	- -	Benzoic acid.
"New Process" ketchup,	Gordon & Dilworth, New York, N. Y.,	Benzoic acid.
Libby's chili sauce,	Libby, McNeill & Libby, Chicago, Ill.,	Benzoic acid.
Libby's tomato ketchup,	Libby, McNeill & Libby, Chicago, Ill.,	Benzoic acid.
"Snider's" catsup,	T. A. Snider Preserve Company, Cincinnati, O.,	Benzoic acid.
"Pride of the Farm" chili sauce,	E. Prichard, New York,	Benzoic acid.
"Columbia" chili sauce,	The Mullen-Blackledge Company, Indianapolis, Ind.,	Benzoic acid.
"Armour's" tomato bouillon,	Armour & Company, Chicago, Ill.,	Benzoic and Salicylic acids.
Tomato flip,	Tomato Flip Company, Chicago, Ill.,	Benzoic acid.
"Pride of the Farm" chili sauce,	E. Prichard, New York,	Benzoic acid.
Ketchup,	Van Camp Packing Company, Indianapolis, Ind.,	Benzoic acid.
Van Camp's tomato catsup,	Van Camp Packing Company, Indianapolis, Ind.,	Benzoic acid.

Vinegar.

Fifty-two samples were examined, 12 of which were found adulterated. Of these adulterated samples, 6 were merely below standard and 6 were factitious. The factitious samples were so called second pressing vinegar, made from apple pomace, and were colored with caramel, and some samples of second pressing vinegar were found to be free from artificial coloring matter. The samples of factitious vinegar found adulterated were characterized in one case by a small lead number, was low in ash and was colored with caramel; in two other cases the sample gave no precipitate with lead acetate, yet the other constants were fairly typical of cider vinegar.

Vinegar.

Acid (Per Cent.).	Solids (Per Cent.).	Ash (Per Cent.).	Alkalinity of Ash.	Reducing Sugar (Per Cent.).	Polarization.	Lead Acetate (ppt. c.c.).	Color.
2.80	2.29	0.22	16.2	1.52	+0.3	0.90	Natural.
4.82	1.20	0.16	10.2	-	0.0	0.12	Caramel.
4.78	2.47	0.24	10.8	1.44	—0.2	0.12	Caramel.
4.64	2.23	0.28	24.8	0.71	—1.4	0.00	Natural.
4.50	2.60	0.20	22.0	0.83	—0.8	0.00	Caramel.
5.04	0.35	0.06	-	-	+0.8	0.00	Caramel.

Mr. Hickey of this laboratory has done considerable work upon the determination of the lead number in vinegar. The samples used in the investigation were made by the old-fashioned slow process, and the method employed is similar to that used by Winton and Kreider[1] on maple products, with some changes necessary to make it applicable to vinegar. The lead number is the number of grams of lead precipitated by 100 cubic centimeters of vinegar, and the method for its determination is as follows: place 25 cubic centimeters of vinegar in a 100 cubic centi-

[1] Jour. Am. Chem. Soc., 28, 1204.

meter flask, add 5 cubic centimeters of the standard lead subacetate soluble and dilute to 100 cubic centimeters with water; after standing at least one hour filter, and to 50 cubic centimeters of the clear filtrate add 10 cubic centimeters of dilute sulphuric acid and 100 cubic centimeters of 95 per cent. alcohol, let stand over night, filter through a porcelain Gooch crucible, wash with 95 per cent. alcohol, dry at a moderate heat for a few minutes, cool and weigh. Calculate the amount of lead in the precipitate, subtract this from the amount in 2.5 cubic centimeters of the standard solution, as determined by a separate test, and divide the remainder by 0.125. The Standard lead acetate solution is prepared as follows: dilute a United States Pharmacopœia lead subacetate solution until the specific gravity is 1.25; to 1 part of this solution add 4 parts of water and filter. If this solution becomes cloudy it must be filtered before using and its strength determined again. The results obtained upon these samples of vinegar, together with other determinations, are shown in the accompanying table.

The figures for lead number on the pure cider vinegar show but little variation, and are much more constant than those figures obtained by measuring the precipitate in Hortvet tubes after centrifuging. Determinations of the lead number on malt vinegar show that the figures are high and upon distilled vinegar that they are low.[1]

Analyses of Samples of Vinegar of Known Purity.

Number and Character of Sample.	Solids (Per Cent.).	Acid (Per Cent.).	Ash (Per Cent.).	Reducing Sugars (Dextrose).		Reducing Sugars in Solids (Per Cent.).	Polarization 200 mm. Tube (Ventzke Scale).	Lead Number.
				Before Inversion.	After Inversion.			
1, cider vinegar,	-	-	-	-	-	-	-	0.166
2, cider vinegar,	-	-	-	-	-	-	-	0.134
3, cider vinegar,	1.44	5.16	-	-	-	-	-	0.087
4, cider vinegar,	2.69	8.70	-	-	-	-	-	0.145
5, cider vinegar,	1.50	5.06	0.19	-	-	-	-	0.106
6, cider vinegar,	1.70	4.57	0.38	0.13	0.13	7.6	—1.10	0.106
7, cider vinegar,	2.18	4.60	0.35	0.24	0.24	11.4	—1.87	0.112
8, cider vinegar,	1.75	5.62	0.38	0.12	0.10	6.3	—1.54	0.096
9, cider vinegar,	1.98	5.78	0.32	0.21	0.19	10.1	—0.88	0.114
10, cider vinegar,	2.04	6.30	0.37	0.22	0.20	10.2	—1.43	0.108
11, cider vinegar,	2.10	7.84	0.48	0.11	0.11	5.2	—1.21	0.114
12, cider vinegar,	1.86	6.24	0.40	0.12	0.12	6.5	—0.88	0.108
13, cider vinegar,	1.76	5.74	0.30	0.14	0.13	7.7	—1.10	0.109
14, cider vinegar,	1.50	3.00	0.34	0.09	0.09	6.0	—0.77	0.096[2]
15, cider vinegar,	1.94	5.80	0.46	0.14	0.18	8.3	—0.88	0.129
16, cider vinegar,	1.73	4.84	-	0.16	0.16	9.3	—0.88	0.106
17, cider vinegar,	1.35	4.60	0.32	0.10	0.10	7.4	—0.88	0.087
18, cider vinegar,	1.60	4.72	-	0.12	0.11	7.2	—1.10	0.108
19, cider vinegar,	1.80	7.28	0.40	0.13	0.11	6.7	—1.08	0.076
20, cider vinegar,	-	-	-	-	-	-	-	0.109
21, malt vinegar,	2.40	5.74	0.06	-	-	-	-	0.434
22, syrup vinegar,	1.60	4.48	-	-	-	-	-	0.015

[1] C. H. Hickey. Proceedings of A. O. A. C., 1908, 27. [2] Incompletely acetified.

Summary of Statistics of Foods, exclusive of Milk.

	Genuine.	Adulterated.	Total.		Genuine.	Adulterated.	Total.
Baking powder,	8	-	8	Malt extract,	1	-	1
Buckwheat flour,	1	-	1	Maple sugar,	30	12	42
Butter,	50	4	54	Maple syrup,	19	1	20
Canned fruits and vegetables,	65	1	66	Meat products: —			
Celery salt,	5	6	11	Beef extract,	1	-	1
Cheese,	15	7	22	Canned meats,	17	3	20
Cider,	46	32	78	Hamburg steak,	60	26	86
Cocoa,	27	6	33	Head cheese,	16	-	16
Coffee and coffee extract,	10	6	16	Jellied meats,	2	-	2
Condensed milk,	26	12	38	Lamb's tongues,	7	-	7
Confectionery,	33	-	33	Mince meat,	14	2	16
Corn meal,	1	-	1	Pig's feet,	1	-	1
Corn starch,	8	-	8	Pressed beef,	10	-	10
Cream,	110	60	170	Sausages,	92	2	94
Cream of tartar,	4	-	4	Tripe,	2	-	2
Eggs,	8	-	8	Milk powder,	2	-	2
Flavoring extracts: —				Molasses,	8	-	8
Almond,	1	-	1	Nonalcoholic drinks,	10	2	12
Cinnamon,	2	-	2	Olives,	1	-	1
Clove,	2	-	2	Pickles,	63	4	67
Lemon,	10	2	12	Potato flour,	8	-	3
Orange,	-	2	2	Proprietary foods,	4	10	14
Raspberry,	-	1	1	Raspberry cordial,	1	-	1
Strawberry,	-	1	1	Rye flour,	2	-	2
Vanilla,	36	4	40	Raisins,	1	-	1
Wintergreen,	-	2	2	Salad dressing,	17	-	17
Grape juice,	25	3	28	Shrimps,	4	-	4
Gluten preparations,	4	-	4	Spices,	47	1	48
Honey,	12	-	12	Syrup,	9	1	10
Jams and jellies,	83	12	95	Table sauce,	41	12	53
Lard,	4	1	5	Vinegar,	40	12	52
Malt liquor: —				Wine,	5	-	5
Ale,	8	-	8				
Beer,	4	-	4	Total,	1,117	250	1,367
Porter,	5	-	5				

Drugs.

The character and quality of the drugs examined during the year are shown in the table on page 612. Only such drugs as need special comment will be discussed.

Alcohol.

Three hundred and twenty-five samples were examined, of which 85 were found to be adulterated. The strength of the adulterated samples varied from 40 per cent. to 85 per cent. of alcohol by volume.

Witch Hazel Extract.

Thirty-three samples were examined, all of which were found to be pure. Samples were examined for the presence of formaldehyde and wood alcohol.

Hydrogen Dioxide.

Of the 24 samples examined, 7 were found to be less than the pharmacopœial standard. Several samples were found to contain acetanilide, the presence of which in most cases was marked upon the label. The following samples were found of low strength: Wampole's Hydrogen Peroxide, made by H. R. Wampole & Co., Philadelphia, was found to be 50 per cent. of the United States Pharmacopœial strength; another sample of Wampole's extract was found to be 1.3 per cent. of the required strength. A sample from the American Peroxide Company, New York, was 73 per cent. of the United States Pharmacopœial strength. A sample of Marchand's Peroxide of Hydrogen was found to be 60 per cent. of the required strength. A sample of Grindle & Gompart's Hydrogen Peroxide was 56 per cent. of the United States Pharmacopœial strength.

Beeswax.

The sample of white wax examined was found to be pure. Two samples of yellow wax were found to contain paraffin. One sample, obtained from A. E. Moors of Lowell, proved to consist entirely of paraffin; another sample, from Carlton & Hovey of Lowell, was found to consist of a mixture of 25 per cent. beeswax and 75 per cent. paraffin. In examining beeswax, we make a determination of the index of refraction of the wax at 65° C. The refraction of pure beeswax should not be less than 1.4455; if the sample is below this figure a saponification number will show the percentage of paraffin in the sample, the saponification number of beeswax being very nearly 100, and that of paraffin being 0.

Extract of Licorice.

Both of the samples examined contained about 25 per cent. of corn starch.

Fluid Extract of Ginger.

Ten samples were examined, 4 of which were declared to be adulterated, either by reason of substitution of tincture of ginger or by making the extract with weak alcohol, in which case the oil and resins do not dissolve.

Gin.

Seven samples were examined, 4 of which were found to be low in alcohol. The alcoholic strength varied in the poor samples from 34 per cent. to 42 per cent. by volume. According to the United States dispensatory gin should contain 47.8 per cent. alcohol by volume.

Camphorated Oil.

The 2 samples examined were found to be adulterated. One sample, made by the New York & Boston Drug Company, New York, contained but 8 per cent. of camphor; the other sample, made by the Napier Chemical Company, New York, was found to contain 14 per cent. of camphor. Full strength camphorated oil should contain 20 per cent. of camphor. These oils were examined by means of the polariscope, as described in the report for 1907.

Lime Water.

Four samples of lime water were examined, of which 2 were adulterated. One sample contained scarcely any lime, while the other sample was but little more than half strength.

Oils.

The samples of oil of cassia, oil of lemon, castor oil and cod liver oil were all found to be pure; 2 samples of olive oil were found to be adulterated with cotton-seed oil; the other 60 samples of olive oil were pure. One of the adulterated samples of cotton-seed oil was obtained from the Frank E. Shea Company, Boston, and contained 70 per cent. of cotton-seed oil; the other sample was obtained in a bottle without any label; this sample contained 15 per cent. of cotton-seed oil.

Proprietary Medicines.

Two hundred and eighty-three samples of proprietary medicines were examined, 118 of which were classed as adulterated. The samples examined consisted of catarrh powders, headache cures, various cough and consumption cures, preparations for babies, and tonic wines. The catarrh powders and tonic wines were examined for cocaine; cold cures and preparations for babies were examined for morphine and codeine; headache powders were examined for acetanilide, and most of the liquid medicines were also examined for alcohol. The methods for the detection of cocaine is the same as were mentioned in the 1907 report. In addition to the physiological reaction for cocaine, the alkaloid has been crystallized with platinum chloride solution, and examined under the microscope; the crystals have been found to be very characteristic. The following methods have been employed in the examination of headache powders: extract a portion of the headache powder with chloroform, and evaporate the chloroform extract to dryness upon the water bath; this residue will then contain the active drug. To detect acetanilide, dissolve a portion of this residue in boiling water and cool; if acetanilide is present it will

usually crystallize out after cooling; filter from any precipitate, and divide the filtrate into two portions; to one portion add bromine water, and if acetanilide is present a heavy white precipitate will be produced; to the other portion of the filtrate add a few cubic centimeters of sodium hydroxide solution, heat to boiling and add a few drops of chloroform; in the presence of acetanilide the characteristic odor of phenyl isonitril will be produced. To test for antipyrine, prepare a solution from the chloroform extract, as in the method for acetanilide, dilute considerably, and add a few drops of a ferric chloride solution; in the presence of antipyrine, a deep crimson color is produced, which is discharged by adding an excess of dilute sulphuric acid. To test for phenacetine, boil 0.1 gram of the chloroform residue with 1 cubic centimeter dilute hydrochloric acid for half a minute, dilute with 10 volumes of water, cool, filter, and add a few drops of a solution of chromic acid; if the solution takes on a deep red color phenacetine is present. To detect the presence of caffein, dissolve a portion of the residue from chloroform in warm dilute hydrochloric acid, add a few crystals of potassium chlorate and evaporate to dryness upon the water bath; to this residue add a few drops of ammonia, and in the presence of caffein, a peculiar characteristic purple color will be produced.

A large number of headache powders have been examined, some of which were marked to conform with the law and some were not. In a few cases quantitative determinations of the amount of active ingredients present were made; these are reported in the following table.

No attempt was made to separate the different ingredients in the powders. A table is also appended giving the names of all the other headache powders which were found to contain acetanilide. Most of these powders were marked correctly, and it should not be understood that these powders do not conform to the law, but the names are given on account of the dangerous character of the drugs used.

Preparations containing Morphine.

Several samples were found to contain morphine, which were either not labeled at all or contained more than the amount stated on the package. The quantitative determination of morphine was made by the method of Prescott and Gordin.[1]

Proprietary Medicines containing Cocaine.

A list of the different medicines containing cocaine is appended. In addition to those mentioned in the list, a large number of samples of catarrh snuff have been obtained which were unlabeled; these were put

[1] Jour. Am. Chem. Soc., 1898, 716.

up in bottles very similar to, and in fact almost identical with, those in which the catarrh cures, put up by the Standard Remedy Company, were contained. Quantitative analyses of these powders show them to consist approximately of from 90 per cent. to 95 per cent. of milk sugar, 1.7 per cent. to 2.5 per cent. cocaine hydrochloride, a small amount of sodium bicarbonate and a little menthol. One sample of Standard Catarrh Powder was found to contain 2.29 per cent. of cocaine hydrochloride, a sample of Gem Catarrh Powder was found to contain 2.07 per cent. cocaine hydrochloride, and a sample of A No. 1 Catarrh Cure contained 2.24 per cent. of cocaine hydrochloride.

Proprietary Drugs containing Cocaine.

Name of Drug.	Manufacturer or Wholesaler.
A No. 1 Catarrh Cure,	Standard Remedy Company, Boston.
Opal Catarrh Powder,	Standard Remedy Company, Boston.
Standard Catarrh Powder,	Standard Catarrh Powder Company, Boston.
Ruby Catarrh Powder,	Standard Remedy Company, Providence, R. I.
Crown Catarrh Powder,	Crown Catarrh Powder Company, New York.
Az-Ma-Syde,	Asthma Remedy and Manufacturing Company, Boston.
Nathan Tucker's Specific for Asthma,	Nathan Tucker, M.D., Mt. Gilead, O.
Celerina,	Rio Chemical Company, New York.
Maltine with Coca Wine,	Maltine Manufacturing Company, New York.
Nichols Compound Kola Cordial,	Billings Clapp Company, Boston.
Park's Tonic Wine,	Ropes Drug Company, Salem, Mass.
Kola Cardinette,	Palisade Manufacturing Company, Yonkers, N. Y.
Dr. R. B. Waite's Local Anæsthetic,	Antidolar Manufacturing Company, Springville, N. Y.

Proprietary Medicines containing Morphine.

Name.	Proprietor or Manufacturer.	Amount of Morphine (Grains per Fluid Ounce).
Dr. J. Emery-Coderre's Infant's Syrup.	M. A. McGale, Rouse's Point, N. Y.,	0.60
Cundall's Neutralizing Cordial,	C. B. Cundall & Co., New Bedford,	0.45
Gauvin's Aniseed Syrup, "contains neither morphine nor opium."	- -	0.28
Kopp's Baby's Friend,	C. Robert Kopp, York, Pa.,	0.70
Mrs. Winslow's Soothing Syrup,	The Anglo-American Drug Company, New York City.	0.40

Proprietary Drugs containing Alcohol.

Name of Drug.	Manufacturer or Wholesaler.	Alcohol (Per Cent.).
Bickford's Syrup,	Dr. Bickford, Lynn, Mass.,	19.49
Burgundia Coca,	Burgundia Coca Company, New York, London, Mexico.	15.49
Craig's Cough and Consumption Cure.	- -	19.28
Dr. Gilbert's Peruvian Tonic,	Gilbert Medicine Company, Boston,	20.58
Dr. Stolze's Oxy-Neura,	Oxy-Neura Medicine and Publishing Company, Reading, Pa.	15.68
Grandma's Cough Cure,	- -	5.63
Hale's Asthma Cure,	-	6.63
Laxative Balsam,	H. F. Plummer Drug Company, Beverly, Mass.	10.36
Laxakola Tonic Laxative,	Laxakola Company, New York and Chicago.	14.74
Peruvian Tonic,	Depot Drug Store, Salem, Mass.,	18.68
Robustine,	Con Keefe, Boston,	26.31
Vin de Bergeau,	P. Lebault & Cie., Paris,	15.30
Vin de Quinquina au Madère,	Roberts & Co., Paris	17.57
Vin Durand Diasté,	Paris,	14.57

Following are the results of the analyses of specimens of "headache powders" collected by the inspectors of food and drugs. It will be noted that some of these preparations are correctly labeled, some bear no statement of the presence of acetanilide, and that others bear statements that are incorrect.

Headache Powders.

NAME OF POWDER.	Name on Package.	Statement on Label.	Result of Analysis.
Headache Konseals, ...	E. E. Heinlein & Co., Brighton, . .	Each konseal contains 5 grs. acetphenetidin,	5.8 grs. acetphenetidin.
Dexter's Headache and Anti-pain Powders.	Chas. H. Dexter, Boston, ...	Each powder contains $4\frac{4}{5}$ grs. antifebrin, .	4.8 grs. antifebrin.
Johnson's Improved Headache Powders.	The Johnson Pharmacy, Maynard, . .	An ounce of powder contains 164 grs. acetanilide.	112.8 grs. acetanilide per ounce.
Thayer's Nerve-Rest Headache Powders.	Henry Thayer & Co., Cambridge, . .	Each powder contains 4 grs. acetanilide, .	3.4 grs. acetanilide.
Headache Powders, ...	J. F. Gearan, Boston, ...	Each powder contains 5 grs. acetphenetidin,	3.3 grs. acetphenetidin.
Dr. Kohler's Antidote, ...	Kohler Manufacturing Company, Baltimore, Md.	Each powder contains $5\frac{3}{8}$ grs. acetphenetidin.	2.2 grs. acetphenetidin.
Paine's Headache Powders, . .	Charles Paine, Allston, ...	Each powder contains 4 grs. acetanilide, .	3.98 grs. acetanilide.
Celero Headache Lozenge, . .	The Celero Drug Company, Boston, . .	Each lozenge contains 2 grs. acetanilide, .	2.03 grs. acetanilide.
Headache Powders, ...	The Tremont Pharmacy, Boston, . .	4 grs. acetanilide to each powder, . .	3.4 grs. acetanilide.
Johnson's Headache Powders, .	Walker, Rintels, Inc., Boston, . . .	Each powder contains 4 grs. acetanilide, .	3.95 grs. acetanilide.
Surety Headache Cure, . . .	Gardner & Co., Boston, ...	Each powder contains 6 grs. acetanilide, .	2.98 grs. acetanilide.
Rourke's Headache Powders, .	D. F. Rourke, Boston, ...	Each powder contains 5 grs. acetphenetidin,	4.8 grs. acetanilide.
Lewis' Headache Powders, . .	Lewis, The Chemist, Boston, . . .	Each powder contains 5 grs. acetanilide, 1 gr. phenacetine.	5.6 grs. acetanilide and phenacetine.
Norris' Headache Cachets, . .	Adams House Drug Store, Boston, . .	Each ounce contains 27.2 grs. caffeine, 136.2 grs. acetanilide.	143 grs. acetanilide and caffeine per ounce.
White Cross Headache Powder, .	Harvey D. Watson Company, Allston, .	Each powder contains 3.5 grs. acetanilide, .	2.84 grs. acetanilide.
Headache Powders, ...	Henry A. Perham, Arlington, . . .	Each powder contains 4 grs. acetanilide, .	3.2 grs. acetanilide.
Smith's Headache Powders, . .	John D. Smith, Springfield, ...	An ounce of powder contains 164 grs. acetanilide.	161.1 grs. acetanilide per ounce.
Headache Powders, ...	A. T. Luscomb, Boston, ...	No statement, ...	5.5 grs. acetanilide
Leroy Headache Powders, . .	Albert L. Wyman, Boston, ...	Each powder contains 4 grs. acetanilide, .	3.6 grs. acetanilide.
Bradbury's Capi-Cura, ...	B. F. Bradbury, Boston, ...	Each powder contains 3 grs. acetanilide, .	2.0 grs. acetanilide.
Headache Powders, ...	J. W. Colburn & Co., Boston, . . .	Each powder contains 3.5 grs. acetanilide, .	2.81 grs. acetanilide.
Worcester Headache Relief, . .	A. W. Fuller, Boston, ...	Each ounce of powder contains 127.5 grs. acetphenetidin.	116.91 grs. acetphenetidin.

Headache Powders — Concluded.

Name of Powder.	Name on Package.	Statement on Label.	Result of Analysis.
Superior Headache Powders,	Choate Drug and Chemical Company, Boston.	100 grs. acetanilide in each ounce of powder,	159.58 grs. acetanilide per ounce.
Shawmut Headache Powders,	D. Michark, Boston,	No statement,	7.8 grs. phenacetine.
Omega Headache Powders,	Dodge's Pharmacy, Everett,	No statement,	3.5 grs. phenacetine and acetanilide.
Munkley's Improved Headache Powders.	Munkley & Co., Boston,	No statement,	4.9 grs. acetanilide.
Headache Cura,	Standard Drug Company, Boston,	No statement,	5.7 grs. acetanilide.
Chamberlain's Headache Powders,	W. H. Chamberlain, Dorchester,	No statement,	3.3 grs. acetanilide and caffeine.
Celery and Caffeine Headache Capsules.	Freeman Pharmacal Company, Portland, Me.	Each capsule contains 0.16 gm. acetanilide,	0.12 gm. acetanilide.
Kefaline Headache Cure,	The Kefaline Company, Boston,	It contains 180 grs. acetphenetidinum to the ounce,	195.6 grs. to the ounce.
Travis & Cunningham's Headache Powders.	Travis & Cunningham, South Framingham.	Each powder contains 3 grs. acetanilide,	1.76 grs. acetanilide.
Thayer's Headache Powders,	Chas. F. Thayer, South Framingham,	Each powder contains 3 grs. acetanilide,	1.2 grs. acetanilide.
Curtis' X Ray Headache Powders,	C. L. Curtis, South Framingham,	Each powder contains 3.5 grs. acetanilide,	2.5 grs. acetanilide.
Headache Powders,	Robbins & Rice, South Framingham,	Each powder contains 3.5 grs. acetanilide,	2.43 grs. acetanilide.
Hunt's Cafenacetin Compound,	W. B. Hunt Company, Boston,	Contains 90% acetphenetidin,	90% acetphenetidin.
Headache Konseals or Wafers,	Shubert & Cologny, Boston,	Each wafer contains 4 grs. acetanilide,	3.51 grs. acetanilide.
Headache Powders,	Bank Street Drug Store, North Adams,	An ounce of powder contains 164 grs. acetanilide.	161.2 grs. acetanilide to the ounce.
Headache Powders,	John A. Rice, North Adams,	Each powder contains 5 grs. acetanilide,	3.72 grs. acetanilide.
Fitzgerald's Headache Powders,	J. H. Fitzgerald, Cambridge,	Each powder contains 4 grs. acetanilide,	3.68 grs. acetanilide.
Dr. Davis' Anti-Headache or Half-Hour Headache Cure.	Dr. N. C. Davis, Indianapolis, Ind.,	No statement,	4.93 grs. acetanilide.
Dr. Paxton's Headache and Neuralgia Cure.	Dr. Paxton's Medical Company, Troy, N.Y.,	No statement,	4.42 grs. acetanilide.
Quick Relief Headache Konseals,	Henry Adams & Co., Springfield,	No statement,	3.62 grs. acetanilide and caffeine.
Funny How Quick Headache and Neuralgia Cure.	Funny How Quick Company, Lynn,	No statement,	Contains acetanilide.
Caffeline Headache Tablets,	W. T. Cummings, Winchendon,	No statement,	Contains acetanilide.

List of Proprietary Medicines containing Acetanilide.

Hill's Cascara Bromide Lozenge.
Quimby's Headache Powders.
Dr. Holbrook's Kola Powders.
Hayes' Headache Powders.
Weeks' Break-up-a-Cold Tablets.
Stearns' Headache Cure.
Eames' Celery Crackers.
Garfield Headache Powders.
Laxacold.
Ellis' No. 2 Cold Cure.
Magic Headache Wafers.
Niquette & Farrar Headache Powders.
Dr. Stetson's Revere Headache Powders.
Whitman Headache Powders.
Caffeine Compound Headache Powders.
Revere Headache Powders.
A. D. S. Headache Wafers.
Durgin's Headache Powders.
Buffington's Headache Powders.
Ed. Cura Headache Powders.
Sunshine Headache Powders.
Richards' Headache Powders.
Five Minute Headache Powders.
Caff-Analid Headache Powders.
Headache Cure.

Borax.

Fourteen samples were examined, 2 of which were adulterated. One adulterated sample was marked "Baker's Refined Salborax," put up by W. C. Baker, Springfield; this sample was found to be adulterated with sodium bicarbonate; the other adulterated sample was a sample of Crescent Borax, and contained 90 per cent. sodium bicarbonate.

Spirit of Camphor.

Ninety-five samples were examined, of which only 10 were classed as adulterated. These adulterated samples varied from 60 per cent. to 85 per cent. of the United States Pharmacopœial strength, which shows considerable improvement over the conditions of a year ago.

Whiskey.

Sixty-five samples were examined, 35 of which were declared adulterated. Most of these samples were the so-called compound whiskey, made of more or less pure whiskey with neutral spirits or diluted alcohol, colored with caramel and artificially flavored. In a few cases it is evident that the samples had been watered, as the alcoholic strength was found as low as 39 per cent. by volume.

Spirit of Peppermint.

The 6 samples examined were found not to conform to the pharmacopœial requirements, all of them having been made with weak alcohol, and consequently little if any of the peppermint oil was in solution.

Brandy.

The single sample examined was found to be factitious, being mixed with dilute alcohol, and was artificially colored.

Tincture of Iodine.

Two hundred and seventy-one samples were examined, 35 of which were of low strength. This is a much lower ratio of adulteration than was found last year. Of the pure samples only 12 were below 85 per cent. of the United States Pharmacopœial strength. The improvement noted in the 1907 report still appears to continue this year.

Tincture of Ginger.

The 10 samples examined were found to be pure. This is a decided improvement over the conditions of a year ago, when one-third of the samples brought in were found to be adulterated.

Summary of Drug Statistics.

	Genuine.	Adulterated.	Total.		Genuine.	Adulterated.	Total.
Alcohol,	240	85	325	Oleum ricini,	13	-	13
Aqua hamamelidis spirituosa.	83	-	83	Proprietary medicines,	165	118	283
Aqua hydrogenii dioxidi,	17	7	24	Rum,	1	-	1
Aqua rosæ,	1	-	1	Sodii bicarbonas,	1	-	1
Calx chlorinata,	-	1	1	Sodii boras,	12	2	14
Cera alba,	1	-	1	Sodii phosphas,	9	-	9
Cera flava,	8	2	10	Sodii et potassii tartras,	1	-	1
Extractum glycyrrhizæ,	-	2	2	Spiritus camphoræ,	85	10	95
Fluidextractum zingiberis,	6	4	10	Spiritus frumenti,	27	35	62
Gin,	3	4	7	Spiritus menthæ piperitæ,	-	6	6
Glycerinum,	43	-	43	Spiritus vini gallici,	-	1	1
Linimentum camphoræ,	-	2	2	Tinctura iodi,	236	35	271
Liquor calcis,	2	2	4	Tinctura opii camphorata,	3	-	3
Oleum cinnamomi,	2	-	2	Tinctura rhei dulcis,	1	-	1
Oleum limonis,	1	-	1	Tinctura zingiberis,	10	-	10
Oleum morrhuæ,	8	-	8	Unguentum aqua rosæ,	1	-	1
Oleum olivæ,	60	2	62	Total,	990	318	1,308

General Summary.

	Genuine.	Adulterated.	Total.
Milk,	2,764	1,170	3,934
Foods, exclusive of milk,	1,117	250	1,367
Drugs,	990	318	1,308
Total,	4,871	1,728	6,609

INSPECTION OF LIQUOR.

The police departments of 38 cities and towns have sent in 239 samples of liquor; of which 203 contained more than 1 per cent. of alcohol and 36 contained less than 1 per cent. of alcohol. The following table gives the number and character of the samples obtained from different localities: —

Summary of Liquor Statistics.

CITIES AND TOWNS.	Wine.	Beer.	Cider.	Whiskey.	Jamaica Ginger.	Rum.	Miscellaneous.
Ashland,	1	-	3	-	-	-	
Athol,	-	-	1	-	-	-	1, mixed liquors.
Attleborough,	-	1	-	-	-	-	
Boston,	-	3	-	1	-	-	1, coffee royal; 1, chinese liquor.
Bridgewater,	-	-	45	-	-	-	
Cambridge,	-	1	1	-	-	-	
Charlestown,	-	4	-	-	-	-	
Dracut,	-	-	-	2	-	-	
Everett,	1	-	-	-	-	-	
Fitchburg,	2	-	-	2	-	-	
Foxborough,	-	3	-	-	-	-	
Framingham,	-	-	-	14	-	-	1, gin.
Franklin,	3	-	3	-	-	-	
Gardner,	-	2	-	-	-	-	
Great Barrington,	-	2	-	-	-	-	
Haverhill,	-	7	4	-	-	-	
Lincoln,	-	11	-	-	-	-	
Lynn,	-	4	1	-	-	-	5, mixed liquors.
Medfield,	-	1	-	-	-	-	
Millbury,	1	1	-	-	-	-	
Millis,	-	-	-	2	-	1	1, alcohol.
Natick,	-	3	-	-	-	-	
Newton,	1	-	42	-	3	-	
Norwood,	-	4	0	-	-	-	
Oak Bluffs,	1	1	-	-	-	-	
Palmer,	-	1	-	-	-	-	
Peabody,	-	-	1	-	-	-	
Pepperell,	-	-	-	3	-	3	
Plymouth,	-	-	-	8	4	5	
Quincy,	-	1	-	-	-	-	
Salem,	-	1	1	-	-	-	1, tonic.
Sharon,	-	-	1	-	-	-	
Southbridge,	-	1	3	-	-	-	
Walpole,	-	-	-	-	-	-	1, malt extract.
Wareham,	-	-	-	1	-	-	1, gin.
Westminster,	-	2	1	2	-	-	
Weymouth,	-	-	-	-	1	-	
Woburn,	-	3	-	-	-	-	
Totals,	10	57	107	35	8	9	13

The samples of mixed liquor sent in by the Lynn police department were mixtures of alcohol, sulpho-naphthol and water; the alcohol varying from 1.65 per cent. to 62 per cent. The sample of Coffee Royal sent in by the Boston police department contained 11.08 per cent. of alcohol. The sample of mixed liquor obtained from Athol contained 28.89 per cent. alcohol, and was mixed with a caustic soda solution.

The attendance of the analyst has been required in the lower courts at Boston, South Framingham, Cambridge, Dedham, Brockton, Peabody, Malden, Woburn, Fitchburg, Lynn and Lowell, and in the superior courts of Norfolk, Suffolk, Middlesex, Dukes, Bristol and Essex counties.

Respectfully submitted,

HERMANN C. LYTHGOE.

INSPECTION OF DAIRIES.

BY THE SECRETARY OF THE BOARD.

INSPECTION OF DAIRIES.

During the year ended Nov. 30, 1908, 2,231 dairies were examined by the Board's veterinarian, and the attention of 1,035 proprietors and of boards of health of cities and towns, wherein the dairies were situated or the product thereof sold, was called to a total of 4,165 objectionable conditions. As in former years, suggestions were made as to changes regarded as necessary in the interest of a wholesome supply and of the public health.

Of the total number of dairies examined, 2,213 were situated in Massachusetts and 18 in neighboring States. The extra-state dairies were visited because of the fact that their product is marketed in this Commonwealth, and, if found to be other than the fresh, clean product of healthy cows, is, under the standards fixed in accordance with the provisions of the national law relative to food and drugs, to be deemed to be adulterated, and hence may not enter into interstate commerce.

The following table shows the number of dairies examined in the cities and towns visited, and the percentage found in each place to be commendable: —

Inspection of Dairies, 1908.

City or Town.	Total Number of Dairies examined.	Number of Dairies where One or More Objectionable Features were observed.	Number of Dairies found to be without Objectionable Feature.	Per Cent. Clean Dairies.
Abington,	32	5	27	84.38
Acton,	1	1	-	-
Second inspection,	52	24	28	53.85
Arlington,	1	1	-	-
Second inspection,	8	4	4	50.00
Third inspection,	1	1	-	-
Bedford,	5	3	2	40.00
Second inspection,	41	25	16	39.02
Belchertown,	42	21	21	50.00
Boxborough,	2	1	1	50.00
Second inspection,	32	21	11	34.38
Bridgewater,	18	8	10	55.56

Inspection of Dairies, 1908 — Continued.

City or Town.	Total Number of Dairies examined.	Number of Dairies where One or More Objectionable Features were observed.	Number of Dairies found to be without Objectionable Feature.	Per Cent. Clean Dairies.
Brockton,	45	18	27	60.00
Buckland,	12	7	5	41.67
Burlington,	10	6	4	40.00
Second inspection,	17	10	7	41.18
Cambridge,	9	4	5	55.56
Second inspection,	8	2	6	75.00
Carlisle,	6	2	4	66.67
Second inspection,	35	12	23	65.71
Third inspection,	2	1	1	50.00
Chelsea,	11	5	6	54.55
Second inspection,	13	10	3	23.08
Chicopee,	15	6	9	60.00
Second inspection,	14	3	11	78.57
Clarksburg,	17	4	13	76.47
Cohasset,	1	-	1	100.00
Second inspection,	9	1	8	88.89
Concord,	11	4	7	63.64
Second inspection,	65	11	54	83.08
Third inspection,	9	8	1	11.11
Fourth inspection,	1	1	-	-
Conway,	48	34	14	29.17
Deerfield,	24	17	7	29.17
Dudley,	30	10	20	66.67
East Bridgewater,	53	18	35	66.04
Everett,	9	3	6	66.67
Second inspection,	12	6	6	50.00
Third inspection,	2	1	1	50.00
Granby,	3	2	1	33.33
Second inspection,	13	4	9	69.23
Greenfield,	46	24	22	47.83
Hanover,	16	5	11	68.75
Hardwick,	67	30	37	55.22
Second inspection,	1	1	-	
Hudson,	10	4	6	60.00
Second inspection,	5	2	3	60.00
Hull,	13	5	8	61.54

Inspection of Dairies, 1908 — Continued.

City or Town.	Total Number of Dairies examined.	Number of Dairies where One or More Objectionable Features were observed.	Number of Dairies found to be without Objectionable Feature.	Per Cent. Clean Dairies.
Kingston,	20	8	12	60.00
Lexington,	1	1	-	-
Second inspection,	23	15	8	34.78
Lincoln,	2	2	-	-
Second inspection,	30	19	11	36.67
Littleton,	3	2	1	33.33
Second inspection,	56	33	23	41.07
Third inspection,	1	1	-	-
Lynn,	6	2	4	66.67
Second inspection,	17	4	13	76.47
Lynnfield,	-	-	-	-
Second inspection,	20	9	11	55.00
Malden,	11	7	4	36.36
Second inspection,	8	3	5	62.50
Third inspection,	12	3	9	75.00
Marblehead,	4	1	3	75.00
Second inspection,	21	10	11	52.38
Third inspection,	1	-	1	100.00
Marlborough,	33	18	15	45.45
Second inspection,	43	33	10	23.26
Third inspection,	1	-	1	100.00
Marshfield,	13	4	9	69.23
Maynard,	2	2	-	-
Second inspection,	8	3	5	62.50
Melrose,	12	5	7	58.33
Second inspection,	6	2	4	66.67
Third inspection,	1	-	1	100.00
Middleborough,	31	9	22	70.97
Monson,	14	8	6	42.86
New Braintree,	34	13	21	61.76
North Adams,	28	16	12	42.86
Second inspection,	23	7	16	69.57
Norwell,	20	6	14	70.00
Orange,	13	7	6	46.15
Palmer,	13	9	4	30.77
Plymouth,	45	25	20	44.44

Inspection of Dairies, 1908 — Continued.

City or Town.	Total Number of Dairies examined.	Number of Dairies where One or More Objectionable Features were observed.	Number of Dairies found to be without Objectionable Feature.	Per Cent. Clean Dairies.
Plympton,	14	8	6	42.86
Revere,	3	1	2	66.67
Second inspection,	5	4	1	20.00
Rockland,	17	11	6	35.29
Salem,	10	4	6	60.00
Second inspection,	6	3	3	50.00
Saugus,	7	3	4	57.14
Second inspection,	26	16	10	38.46
Third inspection,	2	1	1	50.00
Fourth inspection,	1	1	-	-
Shirley,	15	5	10	66.67
Second inspection,	13	9	4	30.77
Somerville,	-	-	-	-
Second inspection,	7	-	7	100.00
Southbridge,	15	9	6	40.00
Stoneham,	18	8	10	55.56
Second inspection,	13	8	5	38.46
Third inspection,	1	1	-	-
Stow,	3	2	1	33.33
Second inspection,	24	12	12	50.00
Sudbury,	1	1	-	-
Second inspection,	51	21	30	58.82
Wakefield,	9	2	7	77.78
Second inspection,	12	4	8	66.67
Waltham,	17	8	9	52.94
Second inspection,	33	17	16	48.48
Ware,	63	39	24	38.10
Wareham,	9	4	5	55.56
Second inspection,	7	1	6	85.71
Watertown,	2	2	-	-
Second inspection,	11	4	7	63.64
Third inspection,	2	1	1	50.00
Wayland,	2	1	1	50.00
Second inspection,	30	13	17	56.67
West Bridgewater,	45	21	24	53.33
Weston,	5	-	5	100.00
Second inspection,	24	7	17	70.83

Inspection of Dairies, 1908 — Concluded.

City or Town.	Total Number of Dairies examined.	Number of Dairies where One or More Objectionable Features were observed.	Number of Dairies found to be without Objectionable Feature.	Per Cent. Clean Dairies.
Whitman,	12	2	10	83.33
Williamstown,	11	4	7	63.64
Wilmington,	3	3	-	-
Second inspection,	18	9	9	50.00
Woburn,	7	4	3	42.86
Second inspection,	7	4	3	42.86
Miscellaneous,	159	67	92	57.86
Derry, N. H.,	1	1	-	-
Stamford, Vt.,	17	6	11	64.71
Outside dairies,	18	7	11	61.11
Total Massachusetts dairies,	2,213	1,028	1,185	53.55
Total dairies,	2,231	1,035	1,196	53.61

Under "Miscellaneous" are included dairies situated in the following towns, in no one of which were more than 8 inspected, the examinations having been made for some special reason, and not as a part of a general investigation: —

Adams.
Amherst.
Ashby.
Athol.
Ayer.
Belmont.
Berlin.
Beverly.
Carver.
Dana.
Dover.
Duxbury.
Essex.
Fitchburg.
Framingham.
Gill.
Groveland.
Hingham.
Holliston.
Manchester.
Marion.
Medford.
Montague.
Nahant.
New Salem.
Newton.
Norfolk.
Northfield.
Pembroke.
Phillipston.
Reading.
Royalston.
Scituate.
Shelburne.
Southborough.
South Hadley.
Sterling.
Sturbridge.
Swampscott.
Wales.
Warren.
Warwick.
Wenham.
Winchendon.
Winchester.
Wrentham.

NATURE OF THE DEFECTS TO WHICH ATTENTION WAS CALLED.

Below is presented an analysis of the 4,165 objectionable conditions to which the attention of proprietors and boards of health was called:—

CONDITION OF COWS.

	Defects.	
Herd with tuberculosis,	1	
Herd with eczema,	1	
Herd with cancer,	1	
Herds with mammitis,	4	
Unclean herds,	345	
		352

CONDITION OF BARNS.

Dairy unfit for milk production,	15	
Building unfit for cows,	18	
		33

Light.

Insufficient number of windows,	80	
Windows inadequate in size,	76	
		156

Ventilation.

Additional ventilation needed,	22	
Barn overcrowded,	40	
		62

General Cleanliness.

General uncleanliness of premises,	603
Tie-up in need of cleaning and whitewashing,	688
Accumulated manure,	32
Manure piled back of cows,	8
Horse manure on barn floor,	2
Horse manure used as bedding for cows,	26
Cobwebs,	48
Privy in barn,	19
Barn floor used as a privy,	5
Slaughtering in barn,	3
Lack of proper drainage,	18
Unclean cellar,	10
Tie-up floor in need of repairing,	6
Tie-up in need of new floor,	2

	Defects.	
Horses not separated from cows,	56	
Pigs kept near cows,	44	
Pig feed boiled near cows,	1	
Swill kept near cows,	6	
Swill carried in milk wagon,	1	
Storage of brewers' grains,	7	
Grain kept near tie-up,	22	
Poultry in tie-up,	3	
Decomposing vegetables in barn,	4	
Cowhides on barn floor,	1	
		1,615

Condition of Cow Yards.

Yard in need of proper drainage,	227	
General uncleanliness,	195	
Pools of stagnant water in yard,	9	
Liquid manure in yard,	4	
Decaying vegetables in yard,	3	
Swill in yard,	3	
Remains of a cow in yard,	1	
		442

Water Supplies.

Well exposed to surface drainage,	20	
		20

Milk Rooms.

Milk room needed,	244	
Unclean milk room,	69	
Milk room located in barn,	1	
Milk room unused,	27	
Milk room used for kitchen refuse,	1	
Milk room used for general storage,	7	
Milk room used as hencoop,	1	
		350

Care of Milk and Milk Utensils.

Milk strained: —

(a) In barn,	474	
(b) Back of cows,	12	
(c) Near horses,	4	
(d) In carriage room,	1	
(e) In yard,	1	
(f) In shed,	1	
		493

		Defects.	
Milk cooled: —			
(*a*) On barn floor,	10		
(*b*) Back of cows,	2		
(*c*) Near horses,	3		
(*d*) In unprotected well,	2		
(*e*) In yard,	4		
(*f*) In wagon shed,	4		
(*g*) In drinking trough,	4		
(*h*) In barn cellar,	2		
		31	
Milk handled: —			
(*a*) On barn floor,	205		
(*b*) Near horses,	1		
(*c*) In grain room,	1		
(*d*) In barn cellar,	2		
(*e*) In wagon shed,	4		
(*f*) In house cellar,	3		
(*g*) On house piazza,	1		
		217	
Milk stored: —			
(*a*) On barn floor,	15		
(*b*) Near horses,	3		
(*c*) Back of cows,	3		
(*d*) Near stagnant pools,	1		
(*e*) In drinking trough,	1		
(*f*) In house kitchen,	1		
(*g*) In an unprotected well,	2		
(*h*) In yard,	3		
(*i*) In wagon shed,	5		
(*j*) In barn cellar,	1		
(*k*) In house cellar,	1		
		36	
Unclean faucet of milk cooler,		9	
Unclean water in milk cooler,		5	
Unclean refrigerators,		7	
Milk cooler kept in barn,		1	
Mixer kept in barn,		1	
Cans kept in shed,		1	
Cans kept in barn,		333	
Milk bottled in kitchen,		1	
			1,135
Total number of objectionable features,			4,165

REPORT

UPON THE

PRODUCTION AND DISTRIBUTION OF DIPHTHERIA ANTI-TOXIN AND VACCINE VIRUS

FOR THE

YEAR ENDED NOV. 30, 1908.

REPORT

UPON THE

PRODUCTION AND DISTRIBUTION OF DIPHTHERIA ANTITOXIN AND VACCINE VIRUS

FOR THE

YEAR ENDED NOV. 30, 1908.

The production of diphtheria antitoxin and vaccine has continued under the direction of Dr. Theobald Smith, at the laboratory of the State Board of Health, at Forest Hills. The distribution has been conducted, as before, at the office of the Board.

The total number of packages issued by the Board during the thirteen years and eight months ended Nov. 30, 1908, was as follows: —

	Bottles.
In 1895–1896 (year ended March 31),	1,724
In 1896–1897 (year ended March 31),	3,219
In 1897–1898 (year ended March 31),	4,668
In 1898–1899 (year ended March 31),	12,491
In 1899–1900 (year ended March 31),	31,997
In 1900–1901 (year ended March 31),	53,389
In 1901–1902 (year ended March 31),	40,211
In 1902–1903 (year ended March 31),	33,475
In 1903–1904 (year ended March 31),	41,133
During six months ended Sept. 30, 1904,	22,255
In 1904–1905 (year ended Sept. 30, 1905),	47,387
During fourteen months ended Nov. 30, 1906,	70,424
In 1906–1907 (year ended Nov. 30, 1907),	64,807
In 1907–1908 (year ended Nov. 30, 1908),	94,645
Total,	521,825

The serum was distributed to local boards of health, to hospitals, and to practitioners in 202 cities and towns, 61 of which used more than 100 bottles each. The following table shows the distribution: —

Number of Bottles of Diphtheria Antitoxin distributed from Dec. 1, 1907, to Nov. 30, 1908.

City or Town.	Number of Bottles.	City or Town.	Number of Bottles.
Abington,	10	Bourne,	3
Acton,	12	Braintree,	736
Adams,	207	Brewster,	13
Agawam,	6	Bridgewater,	58
Amesbury,	58	Brockton,	542
Andover,	48	Brookline,	554
Arlington,	135	Cambridge,	2,771
Ashburnham,	25	Hospital,	149
Athol,	143	Stillman Infirmary,	22
Attleborough,	66	Canton,	31
Ayer,	47	Massachusetts Hospital School,	20
Barnstable,	12	Chelsea,	696
Barre,	5	Cheshire,	18
Becket,	24	Chicopee,	117
Bedford,	14	Clinton,	75
Belchertown,	7	Cohasset,	61
Belmont,	49	Concord,	68
McLean Hospital,	8	Dalton,	12
Beverly,	177	Danvers,	149
Billerica,	25	Dedham,	95
Blackstone,	50	Dennis,	6
Boston: —		Dighton,	12
Boston City Hospital,	28,399	Dudley,	6
Boston Floating Hospital,	97	Duxbury,	45
Children's Hospital,	3,167	Easthampton,	70
General supply,	10,877	Easton,	12
Infants' Hospital,	190	Erving,	6
Massachusetts Charitable Eye and Ear Infirmary.	137	Everett,	346
Massachusetts General Hospital,	124	Fall River,	663
Massachusetts Home for Destitute Catholic Children.	87	Falmouth,	15
Massachusetts Homœopathic Hospital.	800	Fitchburg,	250
Massachusetts Infant Asylum,	112	Foxborough,	64
Saint Elizabeth's Hospital,	6	Framingham,	30
Saint Mary's Infant Asylum,	450	Franklin,	12
U. S. Navy Yard,	58	Gardner,	62

Number of Bottles of Diphtheria Antitoxin distributed from Dec. 1, 1907, to Nov. 30, 1908 — Continued.

City or Town.	Number of Bottles.	City or Town.	Number of Bottles.
Georgetown,	30	Lexington,	12
Gloucester,	321	Lincoln,	7
Grafton,	78	Longmeadow,	12
Granby,	16	Lowell,	1,725
Granville,	6	Ludlow,	6
Great Barrington,	6	Lynn,	8,729
Greenfield,	17	Malden,	925
Groton,	18	Manchester,	12
Groveland,	37	Mansfield,	41
Hamilton,	52	Marblehead,	96
Hanover,	6	Children's Island Sanatorium,	67
Hanson,	31	Marion,	25
Hardwick,	175	Marlborough,	92
Harvard,	6	Marshfield,	12
Harwich,	6	Maynard,	28
Hatfield,	17	Medfield,	82
Haverhill,	1,091	Insane Hospital,	208
Hingham,	12	Medford,	309
Holbrook,	71	Medway,	118
Holden,	24	Melrose,	364
Holyoke,	1,133	Methuen,	94
Hopkinton,	184	Middleborough,	12
Hubbardston,	4	Milford,	250
Hudson,	123	Millbury,	60
Hull,	6	Milton,	94
Huntington,	42	Monson,	24
Hyannis,	18	Nantucket,	22
Hyde Park,	156	Natick,	72
Ipswich,	12	Needham,	95
Lancaster,	12	New Bedford,	703
Lawrence,	1,767	Newburyport,	271
Lee,	12	Newton,	454
Leicester,	24	Hospital,	975
Lenox,	18	North Adams,	146
Leominster,	150	North Andover,	66

Number of Bottles of Diphtheria Antitoxin distributed from Dec. 1, 1907, to Nov. 30, 1908 — Continued.

City or Town.	Number of Bottles.	City or Town.	Number of Bottles.
North Attleborough,	12	Shirley,	78
North Brookfield,	6	Shrewsbury,	16
North Reading,	12	Somerville,	2,367
Northampton,	258	Hospital for Contagious Diseases,	963
State Hospital,	111	Southbridge,	52
Northborough,	12	Spencer,	30
Northbridge,	115	Springfield,	1,367
Northfield,	24	Sterling,	6
Mt. Hermon Hospital,	37	Stoneham,	106
Norton,	2	Stoughton,	28
Norwell,	6	Sutton,	29
Norwood,	115	Swampscott,	24
Oak Bluffs,	6	Swansea,	12
Orange,	72	Taunton,	129
Oxford,	6	Templeton,	26
Palmer,	85	Tewksbury,	50
Massachusetts Hospital for Epileptics.	6	State Hospital,	345
Peabody,	248	Topsfield,	87
Petersham,	38	Townsend,	6
Pittsfield,	200	Uxbridge,	18
Plymouth,	60	Wakefield,	162
Provincetown,	12	Walpole,	12
Quincy,	1,207	Waltham,	253
Randolph,	68	Hospital,	1,400
Reading,	248	Ware,	280
Revere,	307	Wareham,	6
Rockland,	24	Warren,	94
Rockport,	46	Watertown,	123
Rutland: —		Wayland,	30
State Sanatorium,	8	Webster,	12
Salem,	966	Wellesley,	156
Salisbury,	12	Wenham,	34
Saugus,	160	West Bridgewater,	11
Scituate,	30	West Brookfield,	6
Sharon,	18	West Springfield,	200
Sherborn,	3	West Stockbridge,	46

Number of Bottles of Diphtheria Antitoxin distributed from Dec. 1, 1907, to Nov. 30, 1908 — Concluded.

City or Town.	Number of Bottles.	City or Town.	Number of Bottles.
Westborough,	22	Williamstown,	12
Lyman School,	12	Wilmington,	130
Westfield,	12	Winchendon,	20
Westford,	27	Winchester,	36
Weston,	14	Winthrop,	60
Westport,	24	Woburn,	123
Weymouth,	259	Worcester,	5,422
Whitman,	37	Yarmouth,	24
Wilbraham,	48	Total,	94,645
Williamsburg,	6		

The total number of tubes of vaccine virus issued by the Board during the four years and two months ended Nov. 30, 1908, was as follows: —

	Tubes.
In 1904–1905 (year ended Sept. 30, 1905),	23,970
During fourteen months ended Nov. 30, 1906,	31,805
In 1906–1907 (year ended Nov. 30, 1907),	45,265
In 1907–1908 (year ended Nov. 30, 1908),	48,768
Total,	149,808

The vaccine virus was distributed as shown in the following table: —

Number of Tubes of Vaccine distributed from Dec. 1, 1907, to Nov. 30, 1908.

City or Town.	Number of Tubes.	City or Town.	Number of Tubes.
Abington,	72	Billerica,	5
Amesbury,	259	Boston: —	
Andover,	8	City Hospital,	1,250
Arlington,	228	General supply,	11,368
Attleborough,	258	Infants' Hospital,	274
Ayer,	103	Massachusetts General Hospital,	175
Bedford,	20	Penal institutions,	2,350
Belmont: —		Braintree,	81
McLean Hospital,	26	Bridgewater,	27
Beverly,	55	Brockton,	20

Number of Tubes of Vaccine distributed from Dec. 1, 1907, to Nov. 30, 1908 — Continued.

CITY OR TOWN.	Number of Tubes.	CITY OR TOWN.	Number of Tubes.
Brookline,	663	Lawrence,	2,095
Cambridge,	1,806	Lee,	100
Canton,	28	Lexington,	97
Chelmsford,	75	Lincoln,	22
Chelsea,	711	Lowell,	24
Cheshire,	10	Lynn,	1,140
Chicopee,	200	Malden,	67
Clinton,	445	Mansfield,	68
Cohasset,	105	Marblehead,	80
Concord,	47	Marshfield,	20
Massachusetts Reformatory,	910	Medfield,	49
Danvers,	296	Medford,	74
Dedham,	588	Medway,	10
Duxbury,	38	Melrose,	358
East Bridgewater,	28	Merrimac,	25
Easton,	10	Methuen,	139
Egremont,	50	Milford,	150
Everett,	374	Millbury,	175
Fall River,	7,279	Milton,	90
Fitchburg,	675	Nantucket,	16
Foxborough: —		Needham,	76
Massachusetts Hospital,	40	Newbury,	6
Framingham,	10	Newburyport,	65
Freetown,	235	Newton,	785
Georgetown,	31	North Adams,	573
Great Barrington,	200	North Andover,	12
Groton,	16	North Attleborough,	184
Groveland,	25	Norwood,	165
Hamilton,	10	Orange,	35
Hingham,	206	Oxford,	120
Holbrook,	75	Palmer,	165
Holden,	22	Massachusetts Hospital for Epileptics.	306
Hudson,	10	Peabody,	5
Hull,	30	Pembroke,	10
Hyde Park,	326	Pittsfield,	3
Lancaster,	30	Plymouth,	108
State Industrial School,	20	Quincy,	926

Number of Tubes of Vaccine distributed from Dec. 1, 1907, to Nov. 30, 1908 — Concluded.

City or Town.	Number of Tubes.	City or Town.	Number of Tubes.
Randolph,	62	Wayland,	20
Revere,	325	Wellesley,	136
Rockland,	154	Wenham,	20
Salem,	125	West Brookfield,	10
Sharon,	12	West Newbury,	13
Sherborn,	10	West Stockbridge,	15
Somerville,	1,180	Westfield,	216
South Hadley,	20	Westford,	40
Springfield,	1,655	Westminster,	80
Stoughton,	40	Weston,	14
Taunton,	895	Westport,	129
Tewksbury: —		Weymouth,	261
State Hospital,	35	Whitman,	30
Townsend,	51	Williamsburg,	9
Wakefield,	317	Wilmington,	25
Walpole,	35	Winchester,	75
Waltham,	410	Woburn,	64
Ware,	70	Worcester,	1,725
Warren,	64	Total,	48,768
Watertown,	124		

REPORT

UPON THE

WORK OF THE BACTERIOLOGICAL LABORATORY

FOR THE

YEAR ENDED NOV. 30, 1908.

REPORT UPON DIPHTHERIA CULTURES EXAMINED DURING THE YEAR ENDED NOV. 30, 1908.

From Dec. 1, 1907, to Nov. 30, 1908, 4,089 cultures were received from 153 cities and towns in the State. Of these cultures, 2,160 were for the purpose of diagnosis and 1,929 were for release from quarantine.

The following table gives the number of cultures received from the different cities and towns and the results of the examinations: —

CITY OR TOWN.	Whole Number of Cultures examined.	Cultures examined for Diagnosis.		Cultures examined for Release from Quarantine.
		Positive.	Negative.	
Abington,	6	-	4	2
Adams,	6	4	2	-
Amesbury,	13	1	3	9
Arlington,	49	6	18	25
Andover,	2	-	2	-
Athol,	93	21	15	57
Attleborough,	21	6	13	2
Avon,	2	-	2	-
Ayer,	9	2	4	3
Barnstable,	7	1	3	3
Becket,	3	-	3	-
Bedford,	2	-	1	1
Belchertown,	1	-	1	-
Belmont,	15	1	8	6
Berlin,	3	-	3	-
Beverly,	88	21	20	47
Boston,	1	-	1	-
Boxford,	4	1	2	1
Bourne,	1	-	1	-
Braintree,	84	33	26	25
Brewster,	9	2	1	6
Bridgewater,	31	7	6	18

City or Town.	Whole Number of Cultures examined.	Cultures examined for Diagnosis.		Cultures examined for Release from Quarantine.
		Positive.	Negative.	
Burlington,	1	1	-	-
Canton,	29	5	13	11
Chelmsford,	1	-	-	1
Chelsea,	186	26	28	132
Cheshire,	4	1	-	3
Clinton,	36	7	18	11
Cohasset,	15	1	11	3
Concord,	39	8	11	20
Danvers,	25	2	17	6
Dedham,	36	9	17	10
Dennis,	3	-	-	3
Dighton,	2	-	2	-
Duxbury,	44	9	9	26
East Bridgewater,	4	-	4	-
Easton,	2	-	1	1
Everett,	191	38	61	92
Falmouth,	7	-	6	1
Foxborough,	29	4	20	5
Framingham,	6	-	6	-
Gardner,	65	7	31	27
Georgetown,	1	-	1	-
Gill,	3	-	-	3
Granby,	2	-	-	2
Great Barrington,	2	1	-	1
Groton,	15	2	8	5
Hamilton,	8	1	4	3
Hanover,	1	-	-	1
Hanson,	3	1	1	1
Hardwick,	4	1	1	2
Harwich,	1	-	1	-
Haverhill,	1	-	-	1
Hingham,	24	3	14	7
Holbrook,	27	5	16	6
Hopkinton,	2	-	2	-
Hudson,	2	-	2	-
Hull,	8	-	7	1
Hyde Park,	69	6	28	35
Ipswich,	1	-	1	-

City or Town.	Whole Number of Cultures examined.	Cultures examined for Diagnosis.		Cultures examined for Release from Quarantine.
		Positive.	Negative.	
Kingston,	1	-	1	-
Lancaster,	28	5	17	6
Lawrence,	57	21	19	17
Lincoln,	3	-	3	-
Littleton,	3	1	2	-
Lynnfield,	1	-	1	-
Malden,	329	45	78	206
Manchester,	1	-	1	-
Mansfield,	23	4	4	15
Marblehead,	81	13	28	40
Marion,	3	-	-	3
Marlborough,	40	8	10	22
Marshfield,	20	4	1	15
Maynard,	1	1	-	-
Medfield,	31	5	10	16
Medford,	172	30	66	76
Medway,	3	-	2	1
Melrose,	222	37	98	87
Methuen,	8	4	2	2
Middleton,	15	1	6	8
Milford,	3	2	1	-
Millis,	25	5	5	15
Milton,	50	4	22	24
Natick,	21	6	8	7
Needham,	39	10	19	10
Newbury,	3	1	1	1
Newburyport,	34	7	11	16
Norfolk,	3	1	1	1
North Adams,	2	-	1	1
North Attleborough,	3	1	1	1
North Reading,	4	-	2	2
Northfield,	6	1	4	1
Norton,	3	-	3	-
Norwell,	11	-	3	8
Norwood,	24	5	14	5
Oak Bluffs,	2	1	1	-
Orange,	8	-	1	7
Oxford,	4	2	-	2

City or Town.	Whole Number of Cultures examined.	Cultures examined for Diagnosis.		Cultures examined for Release from Quarantine.
		Positive.	Negative.	
Peabody,	35	7	9	19
Petersham,	14	1	2	11
Pittsfield,	6	-	-	6
Plymouth,	14	4	4	6
Quincy,	107	23	60	24
Randolph,	17	6	7	4
Reading,	70	17	14	39
Revere,	118	13	59	46
Rockland,	33	-	10	23
Rockport,	15	5	10	-
Salem,	147	17	24	106
Saugus,	76	11	29	36
Scituate,	17	2	9	6
Sharon,	6	2	2	2
Sherborn,	3	-	2	1
Shirley,	49	11	12	26
Somerville,	3	-	2	1
Southborough,	2	-	2	-
Southbridge,	20	4	4	12
Spencer,	4	-	-	4
Sterling,	1	1	-	-
Stoneham,	70	5	14	51
Stoughton,	16	3	9	4
Sutton,	3	2	1	-
Swampscott,	10	-	3	7
Taunton,	20	7	10	3
Templeton,	26	9	3	14
Topsfield,	6	1	2	3
Townsend,	2	-	-	2
Wakefield,	36	7	12	17
Walpole,	25	3	6	16
Waltham,	3	-	1	2
Wareham,	1	-	1	-
Warren,	47	14	13	20
Warwick,	5	1	1	3
Watertown,	69	11	14	44
Wayland,	11	-	6	5
Wellesley,	21	1	4	16

City or Town.	Whole Number of Cultures examined.	Cultures examined for Diagnosis.		Cultures examined for Release from Quarantine.
		Positive	Negative.	
Wenham,	5	1	2	2
West Bridgewater,	3	-	2	1
West Stockbridge,	6	1	2	3
Westborough,	35	6	21	8
Westfield,	6	1	2	3
Weston,	3	-	3	-
Westport,	2	2	-	-
Westwood,	1	-	1	-
Weymouth,	57	17	25	15
Williamstown,	1	-	1	-
Wilmington,	23	5	7	11
Winchendon,	15	6	4	5
Winchester,	58	5	42	11
Winthrop,	61	11	7	43
Woburn,	44	15	21	8
Wrentham,	4	-	4	-
Yarmouth,	1	-	1	-
Totals,	4,089	727	1,433	1,929

REPORT UPON THE EXAMINATION OF SPUTUM AND OTHER MATERIAL SUSPECTED OF CONTAINING THE BACILLI OF TUBERCULOSIS.

From Dec. 1, 1907, to Nov. 30, 1908, microscopical examination has been made of 1,891 lots of sputum and other material suspected of containing the bacilli of tuberculosis. This material has been received from 161 different cities and towns in the State.

The following table gives the places from which the material has been received and the results of the microscopical examination: —

City or Town.	Whole Number of Examinations.	Positive.	Negative.	City or Town.	Whole Number of Examinations.	Positive.	Negative.
Abington,	6	2	4	Boston,	14	1	13
Acton,	5	1	4	Braintree,	3	-	3
Acushnet,	1	-	1	Brewster,	3	-	3
Adams,	20	9	11	Bridgewater,	3	-	3
Amesbury,	9	2	7	Cambridge,	1	-	1
Andover,	14	3	11	Canton,	2	-	2
Arlington,	24	7	17	Charlton,	1	1	-
Ashland,	11	3	8	Chelmsford,	2	-	2
Athol,	2	-	2	Chelsea,	35	6	29
Attleborough,	15	5	10	Chicopee,	2	1	1
Avon,	5	2	3	Clinton,	13	5	8
Ayer,	4	-	4	Cohasset,	1	1	-
Barnstable,	5	2	3	Colrain,	1	-	1
Becket,	1	-	1	Concord,	26	5	21
Bedford,	2	-	2	Dana,	1	1	-
Belmont,	3	2	1	Danvers,	35	4	31
Beverly,	14	8	6	Dedham,	9	1	8
Billerica,	1	-	1	Deerfield,	1	-	1
Blackstone,	18	5	13	Dover,	3	2	1

City or Town.	Whole Number of Examinations.	Positive.	Negative.	City or Town.	Whole Number of Examinations.	Positive.	Negative.
Duxbury,	2	2	-	Lynn,	5	2	3
East Bridgewater,	7	2	5	Lynnfield,	7	1	6
Essex,	3	1	2	Malden,	44	14	30
Everett,	60	20	40	Manchester,	6	-	6
Fall River,	259	104	155	Mansfield,	14	3	11
Foxborough,	15	3	12	Marion,	4	2	2
Framingham,	7	2	5	Marlborough,	16	4	12
Franklin,	2	2	-	Marshfield,	3	2	1
Freetown,	1	-	1	Maynard,	10	6	4
Gardner,	13	1	12	Medfield,	3	-	3
Gill,	2	-	2	Medford,	58	19	39
Gloucester,	1	1	-	Melrose,	18	5	13
Granville,	3	1	2	Merrimac,	2	1	1
Great Barrington,	6	-	6	Methuen,	2	2	-
Greenfield,	4	2	2	Middleborough,	1	-	1
Hadley,	2	-	2	Milford,	11	6	5
Hamilton,	6	3	3	Millis,	4	-	4
Hanover,	11	3	8	Milton,	3	-	3
Haverhill,	1	1	-	Monson,	3	1	2
Hingham,	34	9	25	Montague,	1	1	-
Holden,	11	3	8	Natick,	24	10	14
Holbrook,	4	-	4	Needham,	15	5	10
Holliston,	1	-	1	New Bedford,	1	-	1
Holyoke,	1	1	-	Newburyport,	4	3	1
Hopkinton,	1	-	1	Newton,	2	1	1
Hudson,	4	2	2	North Adams,	13	6	7
Hull,	7	-	7	North Andover,	3	1	2
Hyde Park,	46	13	33	North Attleborough,	22	3	19
Ipswich,	2	-	2	North Brookfield,	1	1	-
Lancaster,	1	-	1	Norton,	7	5	2
Lanesborough,	1	-	1	Norwell,	1	-	1
Lawrence,	96	37	59	Norwood,	12	4	8
Lee,	2	1	1	Orange,	1	-	1
Lenox,	1	1	-	Oxford,	2	-	2
Leominster,	1	-	1	Peabody,	29	7	22
Lexington,	13	1	12	Pembroke,	1	-	1
Littleton,	8	2	6	Pittsfield,	16	6	10

City or Town.	Whole Number of Examinations.	Positive.	Negative.
Plymouth,	7	-	7
Quincy,	71	22	49
Randolph,	13	3	10
Reading,	39	5	34
Revere,	11	1	10
Rochester,	2	2	-
Rockland,	11	2	9
Rockport,	12	4	8
Salem,	47	20	27
Sandwich,	1	-	1
Saugus,	14	5	9
Sharon,	8	2	6
Shelburne,	1	-	1
Sheffield,	1	1	-
Sherborn,	6	1	5
Shirley,	6	-	6
Somerville,	6	-	6
Southborough,	6	3	3
Spencer,	6	3	3
Stockbridge,	1	-	1
Stoneham,	1	1	-
Stoughton,	4	1	3
Stow,	1	1	-
Taunton,	59	17	42
Templeton,	2	1	1
Tewksbury,	1	-	1
Wakefield,	13	2	11
Wales,	2	1	1
Walpole,	11	1	10
Waltham,	1	-	1
Ware,	7	1	6
Wareham,	5	1	4
Warren,	11	4	7
Watertown,	4	1	3
Wayland,	3	1	2
Wellesley,	14	2	12
Wellfleet,	1	1	-
Westfield,	21	3	18
Weston,	2	-	2
Westport,	4	3	1
Weymouth,	27	8	19
Whitman,	20	7	13
Williamstown,	5	-	5
Wilmington,	16	1	15
Winchendon,	2	-	2
Winchester,	14	1	13
Winthrop,	9	3	6
Woburn,	34	13	21
Wrentham,	4	-	4
Totals,	1,891	567	1,324

Summary.

The number of samples of sputum and other material examined for the bacilli of tuberculosis since these examinations were undertaken by the Board is as follows: —

In 1896–1897 (year ended March 31, 1897),	124
In 1897–1898 (year ended March 31, 1898),	236
In 1898–1899 (year ended March 31, 1899),	414
In 1899–1900 (year ended March 31, 1900),	571

In 1900–1901 (year ended March 31, 1901),	746
In 1901–1902 (year ended March 31, 1902),	797
In 1902–1903 (year ended March 31, 1903),	928
In 1903–1904 (year ended March 31, 1904),	1,006
In 1904 (from April 1 to Sept. 30, inclusive),	494
In 1904–1905 (year ended Sept. 30, 1905),	1,090
In 1905–1906 (fourteen months ended Nov. 30, 1906),	1,576
In 1906–1907 (year ended Nov. 30, 1907),	1,705
In 1907–1908 (year ended Nov. 30, 1908),	1,891
Total,	11,578

TYPHOID FEVER.

Widal, Agglutinative, or Serum Test.

During the year ended Nov. 30, 1908, the Widal test was carried out with 934 specimens of blood. Of these specimens, 247, or 26.4 per cent., gave a positive reaction. Specimens were sent in from 117 cities and towns. These facts are shown in detail in Table I. In a second table (Table II.) the specimens, positive and negative, are classified according to the day of the disease on which they were collected. A moderate number of second and third specimens from the same case were examined, so that the total number of tests made is somewhat over the number of cases of disease concerned. The methods used during the year were the same as those previously in use in the laboratory, and they have been amply described in the reports of the year 1900 and the years following.

Table I. — *Widal Test, Dec. 1, 1907, to Nov. 30, 1908, inclusive, classified according to the City or Town from which the Specimen was sent.*

City or Town.	Whole Number of Examinations.	Positive.	Negative.	City or Town.	Whole Number of Examinations.	Positive.	Negative.
Abington,	14	7	7	Canton,	2	-	2
Amesbury,	2	-	2	Chelmsford,	1	1	-
Andover,	8	3	5	Chelsea,	3	-	3
Arlington,	17	4	13	Clarksburg,	2	1	1
Attleborough,	30	7	23	Cohasset,	2	-	2
Ayer,	2	-	2	Concord,	7	3	4
Barnstable,	2	1	1	Danvers,	6	2	4
Belmont,	3	1	2	Dedham,	8	2	6
Beverly,	16	7	9	Dighton,	1	-	1
Boston,	8	-	8	Dover,	5	2	3
Braintree,	1	-	1	Duxbury,	6	2	4
Brewster,	1	-	1	East Bridgewater,	1	-	1
Burlington,	1	-	1	Easthampton,	3	-	3
Cambridge,	5	-	5	Edgartown,	1	-	1

TABLE I.—*Widal Test, Dec. 1, 1907, to Nov. 30, 1908, inclusive*—Continued.

CITY OR TOWN.	Whole Number of Examinations.	Positive.	Negative.	CITY OR TOWN.	Whole Number of Examinations.	Positive.	Negative.
Everett,	24	10	14	Needham,	6	3	3
Gardner,	15	4	11	Newbury,	1	1	-
Gloucester,	8	1	7	Newburyport,	42	14	28
Granville,	1	-	1	Newton,	1	1	-
Hadley,	1	-	1	North Adams,	13	1	12
Hamilton,	8	1	7	North Andover,	1	-	1
Hanover,	3	1	2	North Attleborough,	4	2	2
Hanson,	2	1	1	North Reading,	2	-	2
Haverhill,	2	-	2	Northampton,	4	1	3
Hingham,	10	1	9	Northfield,	1	-	1
Holbrook,	7	5	2	Norwood,	14	3	11
Holden,	10	3	7	Oakham,	1	-	1
Hopedale,	8	1	7	Peabody,	4	-	4
Hopkinton,	1	-	1	Pembroke,	1	-	1
Hudson,	5	2	3	Quincy,	20	4	16
Hull,	26	10	16	Randolph,	3	2	1
Huntington,	1	1	-	Raynham,	1	-	1
Hyde Park,	16	5	11	Reading,	16	5	11
Lawrence,	76	22	54	Revere,	17	3	14
Lexington,	2	-	2	Rockland,	4	1	3
Littleton,	1	-	1	Rockport,	6	2	4
Lynn,	76	22	54	Rutland,	6	2	4
Malden,	11	2	9	Salem,	3	-	3
Marblehead,	2	-	2	Salisbury,	1	-	1
Marlborough,	19	3	16	Saugus,	5	-	5
Maynard,	1	-	1	Scituate,	7	2	5
Medfield,	1	-	1	Sherborn,	3	-	3
Medford,	13	5	8	Shirley,	1	-	1
Medway,	4	2	2	Somerset,	2	2	-
Melrose,	8	2	6	Somerville,	1	1	-
Mendon,	1	-	1	Stoneham,	3	1	2
Milford,	14	1	13	Stoughton,	5	-	5
Millis,	4	-	4	Swampscott,	6	2	4
Milton,	8	1	7	Taunton,	9	2	7
Natick,	43	11	32	Templeton,	1	-	1

TABLE I. — *Widal Test, Dec. 1, 1907, to Nov. 30, 1908, inclusive* — Concluded.

City or Town.	Whole Number of Examinations.	Positive.	Negative.	City or Town.	Whole Number of Examinations.	Positive.	Negative.
Topsfield,	3	1	2	Westport,	1	1	-
Wakefield,	19	5	14	Westwood,	1	1	-
Walpole,	4	-	4	Weymouth,	10	1	9
Wareham,	2	-	2	Williamstown,	1	-	1
Watertown,	9	1	8	Wilmington,	2	-	2
Wayland,	1	-	1	Winchester,	13	5	8
Wellesley,	12	7	5	Winthrop,	19	5	14
Wenham,	1	-	1	Woburn,	12	2	10
Westfield,	9	3	6	Wrentham,	2	-	2
Weston,	8	-	8	Totals,	934	247	687

TABLE II. — *Widal Test, according to Stage of Disease, Dec. 1, 1907, to Nov. 30, 1908, inclusive.*

Approximate Number of Days from Beginning of Disease to Collection of Blood.	Number of Cases. Positive.	Number of Cases. Negative.	Approximate Number of Days from Beginning of Disease to Collection of Blood.	Number of Cases. Positive.	Number of Cases. Negative.
1,	1	10	18,	3	16
2,	8	11	20,	5	12
3,	2	20	21,	7	21
4,	7	28	22,	1	3
5,	11	33	23,	-	3
6,	11	38	24,	1	12
7,	20	54	25,	3	8
8,	22	29	26,	2	3
9,	11	38	27,	2	1
10,	19	53	28,	3	11
11,	7	21	29,	-	2
12,	8	24	30,	1	6
13,	12	19	31,	-	3
14,	19	35	32,	2	2
15,	6	17	34,	1	1
16,	4	12	36,	-	1
17,	3	16	37,	-	1

TABLE II. — *Widal Test, according to Stage of Disease, etc.* — Concluded.

Approximate Number of Days from Beginning of Disease to Collection of Blood.	Number of Cases.		Approximate Number of Days from Beginning of Disease to Collection of Blood.	Number of Cases.	
	Positive.	Negative.		Positive.	Negative.
39, ...	-	1	70, ...	-	1
42, ...	1	2	75, ...	-	1
46, ...	-	1	82, ...	-	2
49, ...	1	-	83, ...	-	1
50, ...	-	3	84, ...	-	2
58, ...	-	1	90, ...	1	1
59, ...	1	-	Not stated, ...	89	106
60, ...	1	-	Totals, ...	247	687
66, ...	1	1			

MALARIA.

From Dec. 1, 1907, to Nov. 30, 1908, 40 blood specimens were received, to be examined for the presence or absence of the malarial parasite. Of these, 5 were positive and 35 were negative. The percentage of positive cases was 12.5.

The following table shows the city or town from which the specimens, positive and negative, were derived: —

City or Town.	Number of Cases.	Positive.	Negative.
Cohasset,	1	-	1
Concord,	1	-	1
Dedham,	4	1	3
Hingham,	1	-	1
Holbrook,	1	-	1
Hull,	2	-	2
Hyde Park,	2	-	2
Middleborough,	1	-	1
Natick,	4	-	4
Norfolk,	1	-	1
North Attleborough,	1	-	1
Norwood,	7	3	4
Quincy,	2	1	1
Stoneham,	1	-	1
Wayland,	2	-	2
Weymouth,	2	-	2
Winchester,	6	-	6
Woburn,	1	-	1
Totals,	40	5	35

HEALTH OF THE STATE.

Report on the Work of the State Inspectors of Health.

By the Assistant to the Secretary of the Board.

Considering the extent of territory of the different health districts, the number of inhabitants, the character of the business carried on, the great variety of duties to be performed by the State Inspectors of Health, and the time required for the proper discharge of the duties, the difficulty of attempting to establish routine procedures, except along certain lines, must be apparent. Likewise, for the same reasons, anything but a beginning in the classification of the details of the work accomplished, for ready access to persons interested in certain phases of the work, cannot be made at the end of the first year's work, if, indeed, it can be made later on. Aside from the factory legislation, which for the most part is specific, requiring an executive office, the more general functions of the State Inspectors of Health are advisory; and the year's work has proved that it is in an advisory capacity to the local authorities that the State Inspectors of Health have accomplished much good in ways which could not altogether be foreseen, and good of a kind that can be recorded only in a general way. For example, as a result of suggestions to local health authorities, and, as occasions arose, to physicians, concerning persons ill with tuberculosis, many persons were better cared for and the public better protected from the ignorant and careless. Largely through the efforts of the State Inspectors of Health, either by conference or letter, or indirectly through action taken by local boards of health, physicians are learning to report cases of the disease promptly, so that health authorities may know where the people who are sick live, and take such steps as are deemed necessary for the protection of the public. When the work was first started it was found that tuberculosis was frequently not reported until the death certificate had been signed.

In advising local authorities as to the details of effective quarantine measures, including proper methods of cleansing rooms of houses vacated by tuberculous patients, upon the removal or death of the patient, it is difficult to overestimate the services of the State Inspectors of Health. Good was accomplished not merely by conferences but by actual field work, the inspectors observing existing conditions, and in some cases accompanying

the local officers and offering suggestions which resulted in more rigid quarantine as well as in the adoption of better local regulations. A considerable number of so-called "boards of health" displayed gross ignorance in health matters; not knowing the first principles of preventive medicine, they consequently did not take proper precautions to prevent the spread of disease.

Persons found or reported ill with tuberculosis, and careless in their personal habits, were visited and instructed as to the precautions which they must take for their own good and for the safety of others. Those who were found ill with tuberculosis and who appeared to be endangering the health of others were called to the attention of the proper authorities and cared for.

When visiting factories for the purpose of studying health conditions, the State Inspectors of Health made an effort in several ways to secure the assistance of employers, superintendents and overseers in preventing the spread of tuberculosis. One way was by urging superintendents and overseers to take interest enough in the physical condition of the employees to note whether any appeared to be in ill health, unusually pale, or to have a cough that lasted three or four weeks, and to inform the State Inspector of Health of any such person, in order that a proper course of action might be taken. Another way was by frankly stating to the employer that there is no law by which adults working in factories may be examined, and that an examination of certain persons by permission of the employer and the persons whom the State Inspector of Health wished to examine would be for his interest as well as for theirs, and for the welfare of all the employees. In either case a person judged by the State Inspector of Health to be ill with a communicable disease could then be referred to the local health authority, and, if deemed advisable, to the patient's family physician, to a State institution or to social service workers. A commendable way in which some employers helped to prevent the spread of tuberculosis in factories was by paying the expenses for a considerable period of time at the State Sanatorium, or some other hospital, of persons in their employ who were beginning to show symptoms of this disease. At least two firms in different health districts announced the fact that they had adopted such a plan in behalf of their employees; while a number of other firms, although they were quite as much interested in the welfare of their employees, and took similar action in individual cases, preferred not to have the facts generally known.

The large number of minors giving tubercular family histories, as well as the number suspected of having tuberculosis, or of being in the pretubercular stage, although no definite signs could be detected at the time of the examination, led to the use of a special card whenever a diag-

nosis of tuberculosis was made, whenever doubtful signs of tuberculosis were discovered or whenever a minor gave a history of tuberculosis in his family. At the same time the State Inspectors of Health were instructed to call the minor's condition to the attention of the parents whenever a diagnosis of tuberculosis was made, or, if advisable, whenever the case was doubtful. In suitable cases the assistance of district nurses or certain relief agencies was sought in aiding to improve the minor's conditions. By means of a card system the State Board of Health had opportunity, through the State Inspectors of Health, to confer with local health authorities relative to taking measures to prevent the spread of the disease. For example, if a card showed that a member of a minor's family had recently died of tuberculosis, and the minor appeared predisposed to the disease, the attention of the local board of health could very properly be called to the case, in order that an agent of the board might visit the family to see that sanitary home conditions were maintained. Moreover, some unreported cases of tuberculosis have in this way been brought to light, since each minor was asked concerning the health of the other members of his family. In all such cases great care was taken to prevent the spread of infection, and special advice was given to the minors.

For the first few months the State Inspectors of Health were encouraged to submit such reports as they saw fit concerning the health of minors, during which time a careful study was made of the industries with which the minors were associated. One State Inspector of Health, after an experience of eight months, reported that the duty of informing himself concerning the health of minors, while undoubtedly one of the most valuable and important duties incumbent upon State Inspectors of Health, was still the most unsatisfactory, because the territory in his district was so extensive, and the factories employing large numbers of minors so numerous, that the minors could not be visited often enough to permit proper oversight. Another State Inspector of Health, with a similar experience, stated that he knew of no part of the work which called for so much time and patience as that of examining minors. The first formal requirement of the State Board of Health was that the State Inspectors of Health should submit a brief statement concerning each minor, showing (*a*) the name and address, (*b*) the age, (*c*) the kind of work which the minor was found to be doing, and (*d*) an opinion as to health. Previous to this routine, the minors were not individually questioned, unless, now and then, one appeared not to be healthy, or unless distinctly unhygienic surroundings were observed. Whether the minor was questioned at his work, or in an office, hallway or as quiet a place in the factory as could be found, was a detail which was left with the State Inspector of Health to decide. If the minor

looked and acted as if he enjoyed good health he might be passed by without further inquiry than concerning his age and work, or he might be asked if he was well and strong, and his personal and family histories obtained. Whenever a minor appeared to be ill, or if ill health was suspected, more definite information was acquired later, including as careful a physical examination as the place and conditions permitted. Minors exposed to dangerous processes, regardless of appearance and personal or family history, were likewise examined physically. In every instance, whether or not a physical examination was made, each State Inspector of Health submitted a concise report on the immediate sanitary conditions under which the minor was found at work, apart from the general report on the lighting, ventilation and cleanliness of the factory.

The State Inspectors of Health were instructed that all hygienic conditions might be classified under two main groups. Under group 1 they were to consider whether any or all of the minors in a given factory were exposed to dangers which were incident to the occupation; under group 2, whether any or all of the minors were exposed to conditions which were not indispensable to the industry, which might give rise to injurious effects because of the disregard of proper hygienic precautions. If one or more minors were found to be exposed to the dangers of group 1, a statement was made as to whether the dangers were, to a certain extent, avoidable, or whether they were unavoidable. If a minor was found exposed to conditions referred to under group 2, the State Inspectors of Health mentioned the conditions, and expressed an opinion as to what practicable precautions might be taken.

The occupation was in some instances unsuited to a minor's physical condition, it being unattended by dangers of an intrinsic nature, but attended by unhygienic conditions not entirely avoidable: —

E. C., aged seventeen; at work in an oil-cloth factory where 12 minors, sixteen to twenty years of age, were employed, 11 of whom were in good health. This boy appeared anæmic and thin, although a physical examination revealed no disease. He was found working under unfavorable conditions, being constantly exposed to excessive heat and moisture in a dark, ill-ventilated room, and it was found that his mother died of tuberculosis. The State Inspector of Health, on a second visit to this factory, found that the minor had appreciated his advice and had left the factory.

When the home conditions of a minor, whose physical condition was unsuited to his work, were found to be bad, the problem was more difficult: —

E. M., aged seventeen, small, undersized, anæmic, weighed 110 pounds; lips pale and colorless; heart action irregular; not properly fed or cared for; mother died of phthisis, father a drinking man, home surroundings dis-

tinctly bad. Although this boy was really not fit to work in a machine shop, no one took so much interest in him as his employer, who made the work as easy as possible for him, under good hygienic conditions.

The total number of minors seen and questioned, including those examined physically, was 43,270. Of this number, but 521 were found to be in ill health or physically unfit for work. It does not seem probable, therefore, that all the minors who had any physical disability were discovered, particularly when one considers that it is necessary to put much dependence upon the minor's answer, and that, as a rule, it is the exception to find in a factory a suitable place for questioning and examining the minor, to say nothing of the time it takes to examine large numbers of minors and of the interruption of the minor's work during such procedures. Following are the statistical data relative to the health of minors: —

Health District Number.	Number of Minors Seen and Questioned.					Number of Minors Found in Ill Health.				
	Males.	Females.	Total.	Under 18 Years.	18 Years and Over.	Males.	Females.	Total.	Under 18 Years.	18 Years and Over.
1,	20	2	22	14	8	-	-	-	-	-
2,	291	407	698	395	303	44	39	83	48	35
3,	1,225	1,176	2,401	971	1,430	2	2	4	3	1
4,	2,068	1,645	3,713	1,830	1,883	13	11	24	14	10
5,	41	113	154	61	93	4	13	17	7	10
6,	1,025	1,428	2,453	1,217	1,236	43	46	89	44	45
7,	2,199	2,474	4,673	2,036	2,637	17	22	39	23	16
8,	2,083	3,086	5,169	2,499	2,670	10	31	41	17	24
9,	3,256	3,553	6,809	3,243	3,566	14	18	32	12	20
10,	1,352	1,644	2,996	1,423	1,573	1	3	4	4	-
11,	2,000	1,100	3,100	1,759	1,341	3	7	10	1	9
12,	1,370	1,575	2,945	1,564	1,381	5	5	10	5	5
13,	1,123	1,383	2,506	1,222	1,284	14	30	44	28	16
14,	1,893	2,282	4,175	1,969	2,206	63	60	123	97	26
15,	575	881	1,456	786	670	1	-	1	1	-
	20,521	22,749	43,270	20,989	22,281	234	287	521	304	217

Considering the above figures and all the factors entering into the present difficult problem of obtaining information concerning the health of minors in our factories, the question as to the percentage of minors in ill health is exceedingly complex and one for further study. Whether

it can be determined with any degree of accuracy without additional legislation is not certain. Even if this information were at hand, its value would be slight as compared with the importance of figures to show the effect of certain processes or groups of conditions upon the health of minors in different occupations; and such a study can be made only by watching the minors closely until they arrive at adult age, and then by observing those who continue to do the same kind of work under similar conditions. Facts thus gathered, considered with facts obtained concerning the health of all adults who have worked many years in factories, would throw much light upon the entire subject of the effect of industry upon health, and pave the way for exact knowledge in this exceedingly important branch of preventive medicine.

As an experiment, one of the State Inspectors of Health was asked to give practically his whole time for a while to the examination of minors, for the purpose of making a careful study as to their health and physical condition and the conditions under which they were found at work. A record of this study is included in the report of the fourteenth district. This report alone shows clearly that if the sole duty of a State Inspector of Health consisted of informing himself as to the health of minors in factories, even with existing inconveniences and hindrances, many more minors would disclose conditions of ill health.

Another State Inspector of Health spent probably the greater part of his time studying the relation of industries, processes and unhygienic conditions to the health of both minors and adults. This study, based upon the industries located in the fourth district, has contributed considerably to the information previously gathered on the subject of industrial hygiene.

Among the conditions which may affect the health and well-being of mill operatives is light. Until the investigation made in 1905 and 1906, under the direction of the State Board of Health, no extended study of the light in factories had been made in Massachusetts. The State Board of Health in a special report to the Legislature of 1907 pointed out the fact that although good light might not be a necessary factor in all of the various kinds of work, and poor light might not always lead to injury, the effect of well-lighted rooms, if only to exert an unconscious influence upon the minds and spirits of the workers, was highly desirable as a concomitant factor in the maintenance of health. The report showed that too little thought had been given to providing for light in accordance with the kind of work done in the different departments of industries, and it stated the probability that many employees use up a great deal of nervous energy and suffer from eye fatigue or eye strain and its consequences largely because of improper light.

A WELL-LIGHTED WORKROOM. WHITENED WALLS; PRISMATIC GLASS, KEPT CLEAN; SHADES FOR WINDOWS.

A WELL-LIGHTED MACHINE ROOM.

A WELL-LIGHTED WORKROOM.

AN OLD BASEMENT, WITH CLEAN INTERIOR, WELL LIGHTED.

The Legislature of 1907, acting upon a recommendation of the State Board of Health, passed a law providing that "all factories and workshops shall be well lighted." As a result of this legislation, during the present year, more than thirty manufacturers, who previously ignored the fact that it was for their own interests to keep the windows of their factories clean and the walls and ceilings of the rooms whitened, promptly complied with requests or orders of the State Inspectors of Health for such changes as might reasonably be made. Some of the manufacturers did more than was required of them by reconstructing parts of buildings. In several instances, after making changes, the employers found that they could do without artificial light, which, under former conditions, was necessary even on a bright, sunny day.

As an illustration of the change which may be brought about in old buildings, one employer put two new windows in an old basement, and at the same time whitened all the walls and the ceiling. The room was also equipped with numerous incandescent bulbs which, when needed, gave a uniform light. In place of a poorly lighted room, therefore, the employees now have good daylight and good artificial light. A portion of this room is shown in an accompanying photograph.

When the manufacturer knows that it is for his interest to provide good light for his employees, the factory is constructed accordingly. For example, another photograph shows a room where lace is stitched on muslin. The fine designs require good light.

The other two photographs show well-lighted machine rooms, with whitened walls, shades for windows, and, in one of the rooms, prismatic glass.

The improved sanitation of tenement houses, workrooms and factories where clothing is made deserves special mention. By far the most important district where this work is done is the one including Suffolk County, because of the large number of small rooms in congested localities, where most of the work is done by members of a family in one room, which is used as a kitchen, dining room and living room. The work in this district, in fact, was so immense that the State Inspector of Health had but little time for the investigation of other subjects, such as occupational hygiene and the health of minors in factories.

The work in the second district, itself difficult because of its character and magnitude, was made more so by frequent calls for special investigations of conditions alleged by members of labor unions and others to exist, and by the almost constant demand for conferences. The State Inspector of Health was thus considerably handicapped.

Matters relating to water supply, drainage and sewerage received more or less attention by each State Inspector of Health, although by some

much more than by others, according to the needs of the district in connection with the work of the engineering department of the State Board of Health.

The investigation of outbreaks of communicable diseases, made in conjunction with the local health officials for the purpose of taking such steps as were deemed necessary for the protection of the public, has been the means of bringing about more effective local action.

Many schoolhouses and some public buildings were inspected, reported upon, and improved as to cleanliness and ventilating and sanitary provisions. In a few instances the buildings occupied were so unfit for use that, largely owing to the influence and assistance of the State Inspectors of Health, new buildings were provided.

From figures given in the different health district reports it may appear that not all the orders issued were complied with. The fact is, however, that the State Inspectors of Health frequently did not have the opportunity to revisit certain factories before submitting their annual reports, in order to determine whether their orders were complied with. It is the rule of the office that every written order must follow the wording of the statute, and that such orders shall be complied with, although occasionally the compliance of an order has made it necessary for the State Inspector of Health to revisit a factory several times. It was necessary only in a few instances to institute court proceedings for failure to comply with an order.

When determining whether the conditions affecting the health or welfare of the working people in any factory or workshop were in accordance with the law, and the law did not specify the standard of such conditions, the State Inspectors of Health used as standards the conditions which they found existing in those factories and workshops carrying on similar business in similar buildings within the Commonwealth where the health and welfare of the working people were most completely protected. When questions arose in regard to such standards between the said State Inspectors of Health and the person carrying on such factory or workshop, said questions were then referred in writing by the State Inspector of Health to the State Board of Health, which Board investigated and decided said questions, and upon the decision of said Board rested the issuance of an order.

A Record of the Proceedings and Observations of the State Inspectors of Health.

The following report, in accordance with the provisions of chapter 537 of the Acts of 1907, covers the work of the State Inspectors of Health for the year ended Oct. 31, 1908, which date concludes the fiscal year established by that act.

Health District No. 1.

Charles E. Morse, M.D., *Wareham, State Inspector of Health.*

This district includes the counties of Barnstable, Dukes and Nantucket, and the town of Wareham.

The State Inspector of Health spent considerable time consulting with boards of health of the various towns, with the object of obtaining a knowledge of the district and a more universal observance on the part of local authorities of the existing health laws.

Diseases Dangerous to the Public Health.

As a result of these consultations it was found that many of the laws were not being complied with; that some of the boards were negligent in reporting persons ill with diseases "dangerous to the public health" to the State Board of Health; that some boards never reported such; and that some towns had no record book for contagious cases. In some towns no notice of contagious cases was given to the school committee and librarian of the public library. In some of the towns, notably Barnstable and Oak Bluffs, the local boards have done good work towards giving their townspeople a clean milk supply; and the importance of such cleanliness, as a means of preventing disease, was pointed out to every board in the district.

Especial attention was given to the subject of tuberculosis, and, as a result of some suggestions, most of the local authorities will undoubtedly devote more time to watching their tubercular cases, and will be more careful in the matter of fumigating and cleansing apartments after occupancy by such cases, provided they are reported promptly by physicians. Six cases of tuberculosis were reported during the year, and there are now approximately 60 cases of advanced tuberculosis in the district. For the year 1907 the ratio of deaths from tuberculosis to the total number of deaths was 1 to 10 for the district.

Factory Hygiene.

Seven factories were inspected and two orders issued, both of which were complied with.

Health of Minors in Factories.

During the year 22 minors, 20 males and 2 females, were seen and questioned, 3 of whom were examined because of a tubercular family history. None of the minors showed evidence of ill health, and none appeared to be exposed to possible unhygienic influences while at work.

Hygiene of Public Buildings and Schoolhouses.

Three public buildings were inspected, all of which were found to be clean, well lighted and in good condition. The ventilation was by means of windows and doors.

Four schoolhouses in Wareham were examined. In one building the teachers complained of bad odors from water-closets in the basement. The complaints were justified, and the matter was taken up with the school committee

and the ventilating system satisfactorily repaired. In this building the rooms were well lighted, the light coming from (*a*) either side of the pupil, (*b*) the pupil's back and left, (*c*) the pupil's back and right. The windows were clean. The rooms were somewhat dirty and the floors not in good condition.

In another schoolhouse visited the light came directly from the front of the pupils. Ventilation was by doors and windows only. The floors were very bad, and the room dusty and dirty. The school committee promised to abandon the use of the building for school purposes at the end of the 1908–09 school year.

In another schoolhouse the rooms were well lighted, the light coming from both sides of the building. Ventilation was by cold-air ducts from the outside. The exit of air was into a ventilating shaft, in which a small stove should be kept burning, but the stove was out of order at the time of visit. The floors were in poor condition and the rooms were very dusty.

The other schoolhouse visited was well lighted, the light coming from over both shoulders of the pupils. Ventilation was by cold-air ducts from the outside. The exit of air was into a ventilating shaft, as in the building previously mentioned. The stove in the ventilating shaft was out of order at the time of visit. The rooms were dusty and the floors were in bad condition.

All the unsanitary conditions referred to were called to the attention of the school committee, and efforts were made to improve them.

Health District No. 2.

Adam S. MacKnight, M.D., *Fall River, State Inspector of Health.*

This district includes the cities of Fall River and New Bedford, and the towns of Acushnet, Berkley, Dartmouth, Dighton, Fairhaven, Freetown, Marion, Mattapoisett, Rehoboth, Rochester, Seekonk, Somerset, Swansea and Westport.

The work of the year consisted of the sanitary inspection of the district: continuous co-operation by conference and letter with the local health authorities; inspection of factories and the examination of minors in factories: investigating local nuisances, and obtaining information relative to public water supplies.

Diseases Dangerous to the Public Health.

Patients suffering from contagious diseases were found, in some instances, not properly quarantined, and the premises were not thoroughly disinfected after the recovery or removal of the patient. Tuberculosis was frequently not reported until the death certificate had been signed, and it appeared that when cases were reported comparatively little was done in the district to check the spread of the disease.

Following are the replies of two boards of health made in answer to an inquiry as to regulations concerning the release of diphtheria patients:—

As there has been no case of diphtheria during the term of office of the present board of health, we are not posted in our duties in a case of that kind.

Will state that our board of health is the selectmen. We are not posted in such matters as you refer to, and always leave them with the physician in charge of the case.

The health authorities of Fall River and New Bedford require two consecutive negative cultures before a patient is released from quarantine after being ill with diphtheria; those of Berkley, Fairhaven, Freetown, Marion and Rehoboth leave the matter of release cultures to the discretion of the attending physician.

A conference was held with the quarantining physician and the immigration officer of the New Bedford board of health relative to the existence of bubonic plague in the Azores Islands, and information obtained as to the methods employed to prevent a possible entrance of the plague into the New Bedford port.

A Dangerous Practice.

Because of alleged conditions existing at the Brayton Avenue public school in Fall River, the State Inspector of Health visited this schoolhouse, and found that it was the custom to examine systematically the throats of the school children by means of an ordinary school ruler, using it first on one child, then on another, without sterilizing or disinfecting it. The attention of the superintendent of schools was called to this custom and the practice was stopped.

Local Nuisances.

A number of local nuisances were called to the attention of boards of health, together with suggestions for their abatement. The Fall River board of health abated a number of nuisances, consisting of collections of filth, ashes and rubbish, and at the suggestion of the State Inspector of Health made marked improvements in the conditions of Sandy Beach and Lannigan Beach, two popular summer resorts.

The attention of the Somerset board of health was called to a nuisance caused by an offensive trade. In this instance the conditions were so bad that the board of health closed the works. Unsanitary conditions in a waiting room of a street car company were much improved through the action of the local board of health. A nuisance caused by an overflowing cesspool was abated.

The board of health of Swansea abated a nuisance created by the dumping of fish in a vacant lot. Unsanitary conditions of the water-closets in Ocean Grove were reported to the Swansea board of health, which maintained that said conditions could not be improved on account of the tidal changes.

Enforcement of the Spitting Laws in Street Cars.

The attention of the Dartmouth & Westport Railway Company, as well as the boards of health of New Bedford, Dartmouth, Westport and Fall River, was called to the fact that mail bags were frequently contaminated by expectoration while being carried on the cars. The postal authorities of Fall River were also notified of this fact and prompt action was taken by all

the authorities. Strict orders were issued by the superintendent of the street railway company prohibiting the practice of expectorating while the mail bags were being transported. The postal inspector of Boston also acted in the matter, and it was assured that there would not be a continuance of this nuisance.

The attention of the superintendent of the Old Colony Street Railway Company was called to the absence of antispitting notices in cars, with the result that every car has since been supplied with two such notices. Ventilation of street cars was found to be very poor. As a result of a communication sent to the superintendent, the motormen and conductors were instructed to open both car doors at the end of each route, and to allow them to remain open until the car started.

Factory Hygiene.

During the year 40 factories were inspected and 16 reinspected. Fifty-nine orders were issued to manufacturers calling attention to violations of the law. Of this number, 57 were complied with.

A great deal of time and attention was given to avoidable unhygienic conditions and to processes carried on in various industries which might affect the health and comfort of the employees.

It may be said that many changes, some of which were very extensive, were brought about in the sanitary conditions of the mills in the district by oral suggestions to the manufacturers. For example, in one mill city water was introduced for drinking purposes as well as for use in the humidifiers; the arrangement of the machinery was changed to secure better light; alleyways were made wider; new floors were laid in certain portions of the mill; ceilings were whitewashed; walls were painted; and dust-removing devices were rendered more effective. In another mill the windows were enlarged and the ceilings whitewashed and walls painted, thus providing better light; ventilation was improved; the water-closets were reconstructed, and new floors were laid.

It appeared to the State Inspector of Health that a number of unsanitary conditions in mills were caused by the slovenly and dirty habits of some of the employees. A not uncommon custom is to heat dinner pails in buckets of water into which steam is turned from pipes arranged for the purpose. The contents of the pails may run over into the buckets, or water from the buckets bubble up and run into the pails. The condition of some of the buckets is very disgusting. After the meal the water in them is commonly used for washing the face and hands, and sometimes the feet. Waste material and particles of food are thrown under the machinery, around the sinks, into fire pails and other places which are not easily accessible. The result is that, after a time, decomposition sets in, causing nauseating odors in the workroom. The lack of proper washing facilities in mills is to be deplored. The tenements where most of the employees live have no bath rooms, and many employees have not sufficient change of clothing.

Light.— While the general condition of the mills as to light was good, in

many instances, where artificial light was necessary, electric incandescent bulbs were found so covered with dust and so dirty as to interfere seriously with the light. In but one case was it necessary to issue an order to provide for further or different means for improving the light.

Ventilation. — Ventilation of the mills visited was, as a rule, unsatisfactory. In 5 instances ventilation was distinctly inadequate, and orders were issued and complied with for improved ventilation. A higher standard of cleanliness was required in 6 mills. In 1 case better means for the removal of dust, generated in the course of manufacturing processes, was provided.

First-aid Outfits and Sputum Receptacles. — With but few exceptions first-aid outfits and sputum receptacles were provided in the factories and workshops in the cities and the large towns in the district. In Fall River and New Bedford the first-aid outfits generally were kept in the main offices of the mill, where they were not easily accessible in cases of emergency. Mill men were found to be unanimous in their condemnation of these outfits, maintaining that they carried employers' liability insurance, and that in case of an accident legally appointed surgeons were sent to the mills. Those in charge asserted that the outfits were seldom used.

The subject of sputum receptacles in factories still continues to provoke a great deal of controversy among employers and members of boards of health. Some employers object to sputum receptacles of any sort, on the ground that factories are cleaner without them, and that their presence encourages the habit of expectoration; others object on the ground that the presence of sputum receptacles increases the dangers of accidents, since they may get into the passageways and between the machinery. In accordance with a suggestion of the State Inspector of Health, the Fall River board of health distributed antispitting notices to nearly every factory and workshop in the city. Some employers preferred to have their own notices printed.

Drinking Water Supply. — In some buildings, owing to the scarcity of faucets, water was distributed throughout the mills in open pails.

Artificial Moisture. — The State Inspector of Health notified the superintendent of a mill in Fall River that the practice of using stagnant and offensive water for wetting filling was not in accordance with the statute relative to the use of water for humidifying purposes in factories. The matter was investigated by the mill authorities, who acknowledged the use of water which gave rise to foul odors, and, at an expense of about $135, changed the supply to city water.

Health of Minors in Factories.

Six hundred and ninety-eight minors were seen and questioned during the year, and 116 physical examinations were made because of the appearance of a minor, of the minor's occupation and of his personal or family history. Of the minors thus examined 83 were found in ill health (44 males, 39 females), 48 of whom were under eighteen years of age. Of the conditions of ill health mentioned, malnutrition and anæmia represented 39, or nearly

half the cases discovered. Other conditions of ill health found were 10 cases of ocular disturbance, 6 nasal and 3 pulmonary. Among the 25 miscellaneous conditions of ill health or physical unfitness discovered were 1 case of chronic epilepsy, 2 of arrested development, 1 of spinal curvature, 2 of cardiac neurosis and 5 of infectious diseases. None of the minors found in ill health worked in departments in which processes dangerous to health were conducted, although 53 of the 83 minors discovered in ill health were exposed to possible unhygienic influences. In only 2 instances was it deemed necessary to notify the parents of the ill health or physical unfitness of a minor. In one of these cases a boy was taken from the mill and given outside employment; in the other, a girl found to be afflicted with epilepsy was sent to a hospital.

Health District No. 3.

Wallace C. Keith, M.D., *Brockton, State Inspector of Health.*

This district includes Plymouth County, exclusive of the towns of Marion, Mattapoisett, Rochester and Wareham, and, in addition, the towns of Cohasset and Weymouth.

Diseases Dangerous to the Public Health.

During the year visits were made to all the boards of health in the district, and the boards were urged to see that cases of diseases dangerous to the public health were promptly reported. Many observations pointed to the fact that physicians frequently neglected to report promptly the occurrence of communicable diseases. Following is a case in point: a child ill with diphtheria was not reported until near the time of death; the house was not quarantined until later, when a second child became ill with the same disease.

Failure to report diseases in accordance with the statutes was especially noticeable in respect to tuberculosis. An investigation in 22 towns in the district revealed the fact that the health authorities of Carver, Cohasset, East Bridgewater, Hanson, Lakeville, Pembroke, Plympton and West Bridgewater did not require notification of tuberculosis. In answer to the question whether it was customary to disinfect premises after a death from tuberculosis, 12 boards of health replied that such premises were disinfected, while the boards of health of East Bridgewater, West Bridgewater, Lakeville, Pembroke and Weymouth had not practiced such disinfection.

Factory Hygiene.

During the year 105 factories were inspected; 95 were reinspected. One hundred and forty-six orders were issued to manufacturers, calling attention to violations of the law. Of this number, 145 were complied with. Two-thirds of the changes made were relative to providing proper water-closets, sputum receptacles and first-aid outfits. Ventilation was improved in 15 instances; more efficient dust-removal devices were provided in 4; a higher standard of cleanliness was maintained in 17; and in 6 factories changes

were made to improve the light. In 1 factory water was used from a well which was exposed to pollution. Acting upon the advice of the State Inspector of Health this factory was connected with the city water.

The ventilation of shoe factories, while found to be reasonably good during the fall, when the windows were open, was unsatisfactory in the cold weather, particularly in rooms where machines which radiate much heat were used. Wherever it was thought practicable orders were issued requesting improvement of the ventilation of a portion or all of a factory.

In some instances very extensive changes were made at the request of the State Inspector of Health in the water-closet and privy conditions. In a few factories old-fashioned privies were replaced with modern water-closets with good plumbing. In 1 factory a separate closet for women was installed, and in another factory the water-closets and dressing rooms were enlarged. In 1 instance the unsanitary condition of the privies in a factory was remedied by persuading the sewerage commissioners to extend the city sewer to the factory. Connection was then made with the sewer and modern water-closets installed.

During the year the State Inspector of Health visited 36 mercantile establishments for the purpose of finding out whether seats were provided for women employees, but no violation of the law was discovered.

Health of Minors in Factories.

The minors examined were found to be in good physical condition. In several instances certain home conditions were revealed which were inimical to health. For example, it was not infrequently found that 4 or 5 minors slept in one room, with all the windows closed. In all such cases the minors were carefully instructed as to the importance of fresh air, proper diet and other points concerning personal hygiene. Of the 2,401 minors who were seen and questioned, 55 were submitted to physical examinations, — 36 because of a tubercular family history, and the other 19 because of an anæmic and poorly nourished appearance. All the physical examinations, however, failed to reveal evidence of any disease. Four of the minors who appeared to be in ill health, although no evidence of disease was discovered, were exposed to possible unhygienic influences.

In none of the 105 factories visited were the sanitary conditions distinctly bad, although 9 showed moderately bad conditions. On the other hand, 14 factories presented conditions which were sanitarily ideal. In 1 factory, where all the employees, both minors and adults, seemed in excellent condition, it was found that the manufacturers concerned themselves with the comfort and health of the employees. The workrooms were high studded, light and airy. There were two emergency rooms with two trained nurses in constant attendance, a well-equipped library, a recreation room, a dining hall where nutritious foods were served at prices below cost, a baseball field, bath houses, and a kindergarten for the children of the employees. The company also owned a number of tenements with modern conveniences which it let to its employees for rentals varying from $1 to $2.50 per week.

Hygiene of Schoolhouses.

In December, 1907, the attention of the school authorities of Rockland was called to the poorly ventilated condition of the Rockland High School. The matter was taken up for consideration at the town meeting, and an appropriation was made for the erection of a new school building.

In April, 1908, the Center Primary School and the high school, Kingston, were inspected. The ventilation of both these schools was found to be inadequate, and the primary school overcrowded. These matters were brought to the attention of the authorities, and it was voted at the town meeting to build a new primary and grammar school, and to reconstruct the old Center Primary School. The primary school was reconstructed during the summer and was ready for occupancy in the fall.

The attention of the school committee of Brockton was called to the inadequately ventilated condition of the Perkins School. This matter was brought to the attention of the city government, and as a result a new eight-room building is under construction. The Brett School building in Brockton, which has been unoccupied for several years, was put in proper sanitary condition after suggestions were made to the proper authorities by the State Inspector of Health. Likewise, the ventilation of the town hall of East Bridgewater was very much improved during the spring of 1908.

Miscellaneous.

The water-closets connected with the college in Crescent Block, Brockton, were found to be improperly kept. The unhygienic conditions were remedied when the attention of the owner was called to them.

The sanitary conditions in the central railroad station in Brockton, and the Montello and Campello stations, were materially improved. In the Montello station the water-closets were enlarged and connected with the sewer, thus doing away with an old cesspool.

At the suggestion of the State Inspector of Health the ventilation of the Porter Church, Brockton, was improved.

Three nuisances, two of which were privies located near houses and the other the lack of a cesspool for a sink drain, were brought to the attention of the Brockton board of health and were abated. A nuisance consisting of hens kept in the second story of a dwelling house in Brockton was also abated by the board of health at the suggestion of the State Inspector of Health.

HEALTH DISTRICT NO. 4.

ELLIOTT WASHBURN, M.D., *Taunton, State Inspector of Health.*

This district includes the cities of Quincy and Taunton, and the towns of Attleborough, Avon, Bellingham, Blackstone, Braintree, Canton, Dedham, Easton, Foxborough, Franklin, Holbrook, Hyde Park, Mansfield, Milton, Norfolk, Norton, North Attleborough, Norwood, Plainville, Randolph, Raynham, Sharon, Stoughton, Walpole, Westwood and Wrentham.

Members of the boards of health of Attleborough, North Attleborough, Braintree, Canton, Easton, Mansfield, Raynham, Randolph, Quincy, Taunton and other towns in the district have sought advice of the State Inspector of Health from time to time, by telephone, letter or personal visit.

Conferences with Local Authorities.

As the result of a conference with the board of health of Attleborough, the board made and published regulations governing the production and sale of milk in that town. A conference was held with the Walpole board of health on questions as to general duties of that board as to abatement of nuisances, care of milk supply, regulations as to factory cuspidors and emergency outfits, and care of diseases dangerous to the public health.

Local Nuisances.

Assistance was given to the Easton board of health in abating a nuisance of which the worst feature was the discharge of sewage-polluted water into a large pond in the center of the town. Assistance was given to the board of health of North Attleborough as to the best method of abating a nuisance consisting of sink drainage running into a watercourse. As the result of a joint conference by the board of health of Hyde Park, the board of selectmen of that town and the State Inspector of Health, relative to the necessity of draining a sewage-polluted piece of low and spongy land in the town of Hyde Park, a sewer was built.

Factory Hygiene.

During the ten months ending Sept. 1, 1908, the sanitary conditions of 342 factories and workshops, in which the number of employees varied from 5 to 3,300, were examined. The conditions as to light, ventilation and cleanliness varied from sanitarily ideal to distinctly bad. In old factories and mills it was commonly found that the rooms were of insufficient height to permit of the best light and ventilation. Cleanliness was found to vary with the trade pursued. A few workshops appeared to be not only inadequately ventilated, but dirty, owing to the nature of the work conducted therein. For example, the manufacture of oil cloth was found to be attended with the production of oily vapors, and the windows, walls, ceilings and floors were coated with a dark substance like varnish, which made the factory dark and gloomy. Some of the dyehouses were found to be dark and uninviting. As the result of the law requiring receptacles for spitting in factories and workshops, the cleanliness of the floors has shown marked improvement. The majority of the employers have been willing to provide such receptacles, and a considerable number voluntarily posted notices and placards throughout their factories, calling attention to the law relative to spitting. Some of the owners of textile mills object to the use of cuspidors, on the ground of danger to the help from tripping over them and falling against machinery, as, for instance, in the weaving room of a cotton mill. The problem of the best

kind of cuspidor and the number necessary in different factories is gradually working out its own solution. As a rule, the employers have been found to welcome the law, as it gives force to their own individual efforts. In some establishments the overseers have been instructed to discharge any person found spitting on the floor. In the jewelry shops of Attleborough it is an almost universal custom for the superintendent of a room to ascertain every man who is in the habit of spitting, to provide such man with a cuspidor, and to require him to keep it clean. In the majority of towns it appeared that the local health authorities had taken some steps toward the enforcement of the law relative to spitting receptacles. Regulations were made relative to keeping medical and surgical outfits in factories by every board of health in the district.

Letters were sent to 137 manufacturers, calling attention to 332 objectionable conditions, as follows: —

Light. — Four factories were found to be poorly lighted throughout. In 10 factories cleaning and whitening walls and ceilings, and in 7 factories washing the windows, were recommended as simple and efficient means of improving light. In 2 cotton mills, in which the light by day was sufficiently good, it seemed to the State Inspector of Health that the artificial light furnished by kerosene lamps at night must be poor. In one small shoe shop no artificial light was used, and at certain times of the year on dark days, early in the morning and late in the afternoon, the light was bad. Two of the poorly lighted factories were also poorly ventilated, while 8 were below the desired standard of cleanliness.

Ventilation and Removal of Dust. — Inadequate ventilation throughout the building was found in 3 instances; in parts of buildings, 13 instances. The need of hoods, suction pipes, fans, blowers or other means by which the employees could be protected against dust was pointed out in 40 cases. In 1 case attention was called to the desirability of preventing dust from a buffing room from getting into the adjoining finishing room. In 5 cases it was recommended that better care be taken of dust from rattling machines in foundries. Hoods and exhausts for emery wheels were ordered in 29 cases. In 2 instances the exhaust was found to be inefficient on leather buffing machines. The dust in 2 picker rooms and 1 carding room in cotton mills and in 1 carding room in a felt mill was found to be excessive. A number of shops were found to be overheated, some necessarily so because of the trade carried on or the particular process employed.

Acid Fumes. — In 1 instance the employees were improperly protected from the fumes of glacial acetic acid. The conditions here were markedly improved by the installation of a fan.

General Cleanliness. — Under this heading 61 changes were requested, as follows: ceilings and walls need whitening, 10; windows need washing, 7; floors need cleaning, 13; odor from leaky drain, 1; wet cellar, 1; swill on workshop floors, 1; poor cleanliness throughout and a higher standard much to be desired in 28 cases.

Spitting, and Sputum Receptacles. — The attention of the employer was called to the law requiring cuspidors in factories and workshops in 104 instances, and in nearly every case the employer was provided with a printed copy of the statute, and also of the law forbidding spitting on factory floors. The habit

of spitting on the floors by the employees was noted in many instances and commented upon to the employer. A marked desire was noted on the part of most of the employers to break up this habit.

Water-closets. — The following objectionable conditions in water-closets and privies were called to the attention of the proper persons: insufficient number, 1; dark, dirty and insufficient number, 2; water-closet floors, woodwork or walls dirty and need cleaning, 33; insufficient flush, 7; dark and poorly ventilated, 7; wooden partitions perforated, 1; poorly located as to convenience, 2; privy unfit for use, 1; privy woodwork dirty and filthy, 16; improper privy vault, 3; dirty and poorly ventilated privies, 6; separate closets for each sex not provided, 2; not properly designated as to sex, 2; ventilating into workrooms, 12; privy vaults need cleaning, 10; water-closet plumbing defective, 1; leaky bowl or foul seats, 11.

First-aid Outfit. — Written request to install the emergency outfit required by law was made by the State Inspector of Health in 26 cases.

Drinking-water Supply. — In 1 shoddy mill it was found that a fresh and pure supply of drinking water was not provided for the women employees.

Seats for Women Employees. — In 2 cotton waste shops, upon the request of the State Inspector of Health, the proprietors provided proper seats for the women employees, when not necessarily engaged in the active duties of their employment.

Foundry Washing Facilities. — In 1 foundry non-compliance with the law which requires proper washing and water-closet facilities to be provided whenever the foundry is within access to a system of sewerage, was found. Written notice was sent to the owners, calling attention to this violation of the law, who, upon request, were granted an extension of time, in view of the fact that extensive and expensive alterations in the plant are to be made early in the spring of 1909. At another foundry, in connection with a large machine shop, it was found that, while the washing facilities and water-closet accommodations for the foundrymen were not in accord with the special law on these matters, the owners had gone so far in the matter of complying with the law as to procure elaborate plans for proper wash rooms, water-closets and dressing rooms, and were about to install these within a reasonable time. Under these circumstances it was deemed unnecessary to issue a written order.

Humidifiers in Factories. — The sources of water used for humidifying purposes were ascertained, and in no instance was it deemed necessary to call for any change under the special legislative act of 1908.

Results of Written Orders. — In the balance of the year left after the initial round of inspection the State Inspector of Health visited as many as possible of the factories where changes were required for the purpose of ascertaining the results of the orders. Information thus obtained from 120 different factories gave the following data: —

Light. — In 5 cases the light was improved by whitewashing and general cleaning. The problem of improving satisfactorily the light in old, low buildings was found difficult.

Ventilation and Removal of Dust. — The ventilation in 5 factories, representing 11 companies, was improved, by the introduction of fans in 3 instances and by a more intelligent use of windows and ventilators in the others. In 11 plants emery wheels, varying in number, from 2 to 16 per plant, were provided with proper hoods and exhausts, or such appliances were in process of installation; 4 foundries

provided better care for the dust arising from rattlers, — 2 by blowers and 2 by boxing in the rattlers; 2 shoe factories provided, at large expense, complete new systems of caring for the dust arising from leather in the manufacture of shoes; 1 factory provided hoods and exhausts for its "rag wheel" polishing bench; 3 textile mills provided fans for the removal of dust, and a fourth is studying the matter, with a view of installing such as soon as the best appliance can be determined. In 6 instances no protection was provided for the emery wheels, the assigned reasons for non-compliance with the orders being as follows: 1 firm asked, and was granted, extension of time before compliance, as it expected to occupy new buildings soon; 1 plant was shut down; 1 factory had discontinued the use of emery wheels; 1 proprietor asked for extension of time, which was granted, in which he could study the problem of providing hoods and exhausts for emery wheels on which the nature of the grinding was such that practically the whole of the wheels was used, as in grinding large gear guards; 1 promised to provide appliances at once; and 1 assigned no reason. In this latter case it may be necessary to institute court proceedings. In 1 instance an unsatisfactory temporary appliance was installed.

Acid Fumes. — In 1 instance the introduction of a fan greatly improved the conditions in a factory where large amounts of glacial acetic acid were used.

General Cleanliness. — General cleanliness was found improved in 14 plants, — cleanliness of walls by whitewashing, cleanliness of floors by more frequent sweepings or washings, cleanliness of windows by washing and general tidiness. Cleanliness was found to vary somewhat with the day of the week; for instance, the tidiness on Mondays was much better than on days in the last part of the week, as many factories clean up on Saturday afternoons.

One wet cellar was drained properly. One area nuisance, consisting of a leaky drain pipe, from which very objectionable odors entered a machine shop, was abated. One nuisance, consisting of swill on a factory floor, was abated.

Water-closets and Privies. — Water-closets and privies in 42 plants were improved by ventilation, cleaning, repairing or otherwise abating objectionable conditions; in 5 plants old privies were discontinued and new ones built; in 3 instances additional water-closet facilities were provided; in 1 case separate closets for each sex were installed; and in 2 instances closets were properly marked as to sex. The ordinary out-door privy seemed to be almost impossible to keep clean; if found clean at one visit, it was quite likely to be dirty at the next, — and this, too, in spite of the co-operation of the owner in the endeavor to keep it clean.

Drinking-water Supply. — A proper supply of pure drinking water was provided in the 1 mill at which such supply was found lacking at the first visit of the State Inspector of Health.

First-aid Outfit. — Emergency outfits were provided at 17 factories. At 2 plants such appliances were not provided, as the board of health of the particular town in which the plant was located had not specified requirements relative thereto. Many of the factories had supplied such, however, without waiting for action on the part of the board of health.

Sputum Receptacles. — As a result of the orders, 70 factories installed sputum receptacles. It was found that in 4 cases these were not provided, and for no assigned cause; while in 10 instances they were not supplied because the owners were unable to find out the requirements from the boards of health of their respective towns. In every one of the latter cases the State Inspector of Health

wrote to the board of health of the town which had not specified requirements, and in several instances the desired requirements were made.

Oral Orders. — One hundred and thirty-seven oral requests for changes were made. In the cases where oral requests were given instead of written orders, the State Inspector of Health had an opportunity to point out directly to the employer the objectionable conditions.

The oral requests covered the following conditions, namely: spitting on floors, 11; cuspidors required, 71; emergency outfit required, 11; water-closet floors or woodwork dirty, 9; leaky water-closet, 1; walls dirty, 2; poor ventilation, 1; temperature in workrooms too high, 2; water-closets undesignated, 2; other conditions, 27.

No Orders. — In 130 factories and workshops there appeared no necessity for changes.

Health of Minors in Factories, in Relation to the Industry.

Three hundred and fifty-two establishments were visited during the year, and information was obtained concerning the health of minors employed in 69 different industries.

Aluminum. — All of the minors found working at the production of aluminum goods appeared to be in good health, and were working under good sanitary conditions. The lacquer used had a sickening odor, which caused headache and some coughing to beginners at this trade, and drowsiness to 1 minor.

Bleaching, Dyeing and Finishing. — Except for 1 girl, the minor workers in this trade were found to be in good health. Minors worked in parts of the buildings in which no objectionable process was carried on, as a rule, and the workrooms were found to be well lighted and well ventilated, and kept reasonably clean.

Boxes; Paper, Wood and Leather. — In the box-making trade no unhealthy minor was found. All worked under satisfactory hygienic conditions, and were exposed to no deleterious influence.

Celluloid Combs. — No minor employed at making celluloid combs was found to be unhealthy. The sanitary conditions under which the minors worked were not such as to endanger their health.

Chocolate and Cocoa. — One boy employed in the roasting room of a chocolate factory was exposed to cocoa dust, but with this exception all the minors found in the 2 factories visited worked under conditions which were almost sanitarily ideal. No unhealthy minor was found. One factory provided an athletic field and a gymnasium for its employees, including the minors.

Colors and Gums. — No unhealthy minor was found, but the 3 minors who worked at this trade were constantly exposed to starch dust in large amounts, — apparently unavoidably.

Curled Hair. — The 6 young women found employed in the 1 establishment of this industry visited were found to be somewhat pale and not rugged, although the sanitary conditions under which they were working were sufficiently good. Proper precautions were taken to prevent the occurrence of malignant pustule.

Fire Hose. — The 1 minor employed was found to be healthy and working under good sanitary conditions.

Foundries. — Brass: in 2 brass foundries 12 healthy boys were found. The sanitary conditions under which they worked were excellent.

Copper: 8 boys who appeared to be healthy were found in a copper and yellow metal foundry. While the buildings were dark and gloomy, they were adequately ventilated except in the annealing department.

Iron: in 10 foundries making iron castings 16 boys were found. All appeared healthy, and, with the exception of 1 foundry, the conditions as to light, cleanliness and ventilation of the rooms in which they worked were good. In this foundry the standard of general cleanliness was low, and there was considerable dust from tumbling machines where the castings were cleaned.

Beside the minors found in these plants, where the principal business is making castings, some were found in foundries connected with machine shops of various kinds.

Gold Pens. — Two healthy minors working under good conditions were seen.

Ink (Printers'). — One lad who appeared healthy was found working under good conditions in a part of the factory where no injurious process was carried on.

Jewelry. — In the making of jewelry and the trades which accompany it, namely, electroplating and enamelling of jewelry and the refining of gold and silver, were found many minors, who, with but few exceptions, appeared so well that a physical examination was deemed unnecessary.

The hygienic conditions surrounding these young workers in this trade are in the main very good. In 1 electroplating shop the ventilation was inadequate; in 1 jewelry making shop 9 girls were working in an improperly ventilated room; in another, 1 lad worked in a poorly ventilated and overheated coloring room; in another, 2 boys were in a room in which the ventilation was moderately bad; in 1, 2 girls and 1 boy were not properly protected from acid fumes; and again, 5 boys in a factory were subjected to conditions varying from moderately to distinctly bad.

It was discovered that certain parts of jewelry making were done at home by girls who are willing to work at less pay in their own homes than they would receive in the shops, and that the work was paid for by the piece, the girls working as many hours in the day or night as they pleased. It appeared that certain women, or persons, act as go-between for the employer and the outside help, and that the work is all done under the supervision of these persons, who pay the minors their wages; thus the employer is not supposed to know how long the women and girls work. It seems, then, that the law which limits the number of hours per day and per week that females may work in factories is a false protection in this industry.

Leather. — Japanning: 2 factories making patent leather were examined. In them were found 25 minors, none of whom appeared to be unhealthy, although all were more or less constantly exposed to naphtha fumes. In 1 factory the conditions under which the minors worked were judged to be unsuited to them. In the other factory the sanitary conditions were not unsatisfactory.

Novelties: 1 minor employed under good conditions was observed. He presented no evidence of disease.

Tanning: 1 boy was found to have valvular heart disease, but otherwise the minors employed at this trade appeared healthy. The conditions under which they worked, while from the nature of the trade not hygienically ideal, were not bad. It cannot be said that the minors were exposed to unsanitary influences; the work was unattractive, rather than harmful.

Machine Shops. — The following factories and shops were visited: —

Battleships: in 1 plant, making battleships, were found 222 minors, all of whom were boys. They worked under good sanitary conditions, and were required to pass a physical examination at the time of their first employment as apprentices for the firm. The major part work out of doors; their work is as apprentice machinists or iron workers, or apprentice blacksmiths. One ill minor, only, was discovered, and he was found to have *petit mal.*

Blower machinery: 1 large plant visited employed 81 minors, mostly as apprentice machinists or moulders in the large iron foundry attached to the plant. In 2 cases physical examinations were required, but no disease was detected. The minors worked under good conditions. The work was hard, and none but well boys could long stay there.

Cotton machinery: 3 shops employed 115 minors, of whom 2 were girls. One boy who was markedly undersized was found to have no disease. Aside from this minor, the minors were judged to be in good health. The conditions under which they worked were reasonably good.

Electrical goods and ignition supplies: in 3 shops were found 34 minors, of whom 15 were males and 19 were females. All were healthy, and worked under good conditions. At 1 of the factories most of the minors lived in the company's houses, under very good home conditions.

Engines and engine supplies: 5 boys were found in the 3 shops visited, 4 of whom were healthy. The other had a chronic enlargement of the tonsils. The conditions under which the boys were working were satisfactory.

Eyelets: 1 shop in which brass eyelets and 1 in which zinc eyelets are made gave employment to 16 minors, 4 males and 12 females. In each shop the hygienic conditions were good and all the minors were healthy.

Printing presses: 21 boys, none of whom was unhealthy, were found at work under satisfactory sanitary conditions in the 2 shops visited.

Taps and dies (steel): in 3 shops of this industry were found 38 minors, of whom all but 1 were males. One boy at a milling machine was pale and thin, but careful physical examination failed to reveal any evidence of disease. All worked under good sanitary conditions.

Tools and twist drills (steel): 5 shops were inspected, and in them were found 61 boys and 1 girl. One boy worked in the turning department of a twist drill factory, and was observed to be undersized, anæmic, and to have colorless lips and an irregular pulse. His mother died of tuberculosis. It was found that the factory conditions, while not satisfactory, were better for the boy than his home surroundings, which were absolutely bad. In another twist drill factory 20 minors were found to be working under moderately bad conditions.

Miscellaneous: the following shops were also examined with reference to the minors: shops making automobiles, 1; automatic machinery, 2; coffin hardware, 1; general machine shop, 3; gears, 1; lathes, 1; milling machinery, 1; slot machines, 1; stamping and nickel plating, 1. In these shops were employed 94 boys and 1 girl. One boy working in the stamping and nickel plating shop was observed to be small, undersized for age and pale, but no disease was found upon examination; 1 lad in an automatic machine shop also required physical examination on account of unsatisfactory appearance, which examination, however, proved negative. With these exceptions all these minors appeared to be healthy. All of the shops were at least satisfactory as to their sanitary conditions, and 1 closely approached the ideal.

Oil Cloths. — But 1 minor employed at this trade appeared unhealthy, and he was employed in the "buckram" department, not, strictly speaking, in any way connected with the making of oil cloth. The minor, a boy, aged seventeen, whose mother died of phthisis, looked anæmic and thin, although on careful physical examination no disease was revealed. He was found working under unfavorable conditions, being constantly exposed to excessive heat and moisture in a dark, ill-ventilated room. At a second visit to this plant it was found that this minor was no longer employed by the company. The conditions under which minors work in oil cloth factories are dingy and unattractive. The real work of oil cloth making is too hard for minors.

Optical Goods (Metallic Frames and Leather Cases). — All of the minors seen at this trade were healthy, and were working under good conditions.

Paper. — One minor, a young woman, aged sixteen, showed scars on her neck, — the result of previous glandular enlargement and subsequent abscesses. She was thin, but no disease was detected. She is to be carefully watched by the superintendent, and sent to the company's physician should cough appear or should she appear ill. This company employs a physician to examine any sickly employees, and when incipient cases of phthisis are found, they are sent to some proper sanatorium at the company's expense.

All the other minors found in this industry appeared healthy, and were working under satisfactory hygienic conditions.

Pearl Working. — Three pearl factories and 4 factories which did pearl working as a part of the trade of jewelry making were visited. Of the minors employed, 24 — of whom 14 were males and 10 females — were in rooms where they were exposed to pearl dust caused by the process of cutting, sawing, grinding and doming pearl shells. A careful physical examination of each of these minors revealed no disease. Thirteen of these minors had worked in the pearl department of some factory during periods varying from three months to five years; 7 for periods of from three to six months; 2 for periods of seven and eight months; 2 for sixteen and eighteen months; and 2 for two and one-half and five years respectively. In 2 of the factories the cutting machines were found to have no hoods and exhausts, owing, perhaps, to the fact that the process of cutting appears to give rise to the least amount of dust of any of the machines used in the dry process in this trade. In the pearl working room of 1 of these factories there was but a slight amount of dust. On the other hand, in another factory all the processes in the pearl workroom were attended with the production of great amounts of pearl dust, in spite of dust-removing appliances on all but the cutting machines. Again, in a pearl workroom in a factory where all the machines were equipped with appliances for protecting employees from dust there appeared to be more dust than the appliances could take care of. In this room 7 female and 4 male minors were employed. Still again, on the other hand, in the pearl workrooms in another factory, where every machine creating pearl dust was equipped with hoods and exhausts, including the process of wet sawing, there was no appreciable amount of pearl dust in the air of the room, and the conditions as to cleanliness were very good. Notwithstanding the effective precautions in this factory, no female minors were here employed, but it was here where the 2 boys who had worked longest (two and one-half to five years respectively) were found.

Rivets, Tacks and Nails. — One hundred and one females and 31 males, a total of 132 minors, were employed at this industry. None of these were found to

be unhealthy, although several who looked pale received careful physical examinations. In 1 factory 2 minors were exposed to fine, white lime dust, although each appeared to be rugged and healthy. In a wire nail factory 5 girls were counting and packing nails. This work was deemed to be trying to the eyes. In the largest rivet factory, employing 107 minors, the sanitary conditions were excellent throughout.

Rubber Goods (Composition, Boots, Fabrics, Heels and Other Goods). — One hundred and twenty-nine minors were found at this trade, of whom 83 were males and 46 were females. In 1 factory 1 girl, aged seventeen, looked pale and thin, but physical examination revealed no disease. In a large rubber boot factory, in which the sanitary conditions were excellent, 3 boys and 1 girl were so markedly undersized as to cause comment, although they appeared healthy. At this factory the majority of 40 minors, males and females, who worked on the cutting floor, were smaller than the general run of minors of the same ages.

Eleven boys working in a rubber clothing factory, and known as "spreader helpers," worked under distinctly unhygienic conditions. It was necessary for them to crawl under the machines, where they assumed a half-doubled-up position, their heads protected from the heat of the machines by planks covered with asbestos. The air under the machines was hot and vitiated with naphtha fumes, and the light in the room was bad. Although no ill or ailing minor was found, all the spreader boys were pale and most of them thin. They were under the spreaders for about ten minutes at a time. The total amount of time spent under the spreader machines varied from a third to a half of their entire working time. It seemed to the State Inspector of Health that minors should not be allowed to do this work.

With the exception of the factory in which these "spreader helpers" work, the sanitary conditions in the rubber factories were found to be reasonably satisfactory.

Sand Paper. — Ten minors working at this industry under fairly satisfactory conditions were found to be in good health.

Shoes and Shoe Fixings. — Shoes: 319 minors, of whom 201 were males and 118 females, were found to be engaged in leather working incidental to the making of some part of boots and shoes. In parts of 1 factory, employing 33 minors, the ventilation was inadequate and there was some leather dust due to the poor draft on the dust-removing appliances. One minor less than fourteen years of age was found in a factory making pasted leather stock for heels, working under improper hygienic conditions as to light, ventilation and general cleanliness. This case was referred by the State Inspector of Health to the State officer having charge of enforcement of the law regarding the employment of children under fourteen years of age in factories. One girl and 1 boy were employed in this factory under the same conditions; the boy was undersized and pale, but no disease was found on careful physical examination. In a shoe factory, working under good conditions, were found 1 small, undersized but healthy boy, and 1 boy who was pale and thin, who presented no disease but who was said to smoke cigarettes to excess. The girls working in the sewing room of this factory were exposed to some naphtha fumes. In the largest shop, employing 136 minors, none appeared unhealthy, and the hygienic conditions under which they worked were very praiseworthy. In still another factory, in which the conditions were neither especially good nor distinctly bad, 1 boy was found who was affected with chorea, and 1 boy who appeared to be convalescent from a severe attack

of influenza, and who was advised to leave the shop temporarily. In this latter shop 2 young girls appeared to require physical examination, but no disease was discovered. In another small factory, in which there was a very poor standard of general cleanliness throughout, 1 boy required examination, which was negative. In this shop the floors throughout were dirty and at certain times of the day, during the winter months, the light must be poor, owing to the lack of any system of artificial lighting.

Shoe buttons, enamelling of: the hygienic conditions in this factory were found worthy of commendation, and no unhealthy minor was found working therein.

Shoe laces: of all the minors found in this trade, but 2 appeared to require a physical examination; of these, 1 was pale, but no disease was found; the other, a girl, was pale and undersized, and appeared to have insufficient food, so that, while no disease was found, she was not fit for factory work. Her employer stated that her father and mother were ill, and that she and her sister supported the family, and that he made her work as easy as possible. The sanitary conditions under which these minors worked were very good. In one factory, in which all the 22 minors appeared healthy, all were exposed to unhygienic conditions, which appeared to be incidental to the trade. The rooms in which the braiding was done were rendered dark by the machinery, which covered practically the entire floor space. The noise from the braiding machines was almost deafening.

Shoe Polishes. — Two healthy minors worked at this trade under good conditions.

Shovels and Spades (Steel). — Twenty minors, all rugged and healthy, were found working in rooms that were low studded and somewhat dark because of small windows of insufficient number, in buildings which were of stone and were old. The work was laborious; no unhealthy minor could long pursue this trade.

Silverware (Silversmithing). — In 12 establishments, making sterling or plated silverware of various kinds, were observed 145 male and 64 female minors, — a total of 209. One boy, aged eighteen, working in a German silver room, who appeared frail and was subject to attacks of rheumatism, was found to have a well-marked mitral murmur. Three minors, 1 boy and 2 girls, in the finishing room of 1 factory, were exposed to dust which came from improperly protected "rag" wheels in an adjoining polishing room. Five boys in another factory were found to be healthy, although the factory in which they worked was generally dirty, poorly ventilated, overheated, and there was much tobacco spit on the floors.

Stove Linings. — In 5 shops were found 16 male minors, all of whom appeared healthy except 2; of these latter, 1 was pale and small but careful physical examination failed to reveal any disease; and 1 showed scars on his neck, as the result of previous cervical adenitis, but physical examination was negative. The mother of this lad died of phthisis. Three boys in one shop and 4 in another shop, including the 2 examined physically, were exposed to more or less dry clay-dust, as a necessary adjunct of the trade. Aside from this, the conditions were reasonably satisfactory.

Stove Polish. — Two healthy minors were found working under good conditions.

Straw Hats. — Two boys working in the sizing room of a straw hat factory were pale and anæmic, but careful physical examination revealed no disease, and their pallor was thought to be due to the constant high temperature of the room in which they worked. In this same factory, 1 girl, whose duty was to trim

loose ends of threads and straw from the hats, looked pale, although examination was negative. Her work was easy and light, although conducted in a hot room. Eight girls worked in another factory in very old rooms, in which the standard of cleanliness maintained was poor. The other minors in this trade worked under good conditions, and with the stated exceptions all appeared to be in good health.

Textiles. — Carpets: in the 1 carpet factory visited were found 89 minors, of whom 32 were males and 57 females. One girl was found who had occasional attacks of malaria; 2 boys in the weaving room were markedly small and undersized, but were healthy; 1 boy in the dyehouse and 1 girl in the ring spinning room were deemed to require physical examination, which, however, revealed no disease. In all the departments in which the minors worked were found none who were working under especially injurious influences.

Cotton cloth, cotton waste, etc.: in these industries 22 factories were visited, in which were found 378 male and 570 female minors, — a total of 948. Of these, but few appeared to be in poor health. Two boys and 2 girls in 2 cotton sheeting factories were observed to be small and undersized. In 1 of the cotton sheeting factories the frame spinning, carding and weave rooms were poorly ventilated, while the light in each room was moderately bad. In 1 cotton sheeting and 1 cotton yarn mill kerosene lamps were used for light. The ventilation was adequate in all the rooms. In the cone winding room of 1 cotton yarn mill, in which 37 minors were employed, the light was bad, as the room was low studded, but the ventilation was good. In the sorting rooms of 2 cotton waste factories the 9 minors employed were exposed to more or less cotton dust from cotton waste, which they picked over by hand; the cotton waste consisted of waste from carding and picking rooms and sweepings from floors, the latter containing more or less tobacco sputum. In another cotton yarn mill, 11 minors in a carding room were exposed to cotton dust, but the ventilation was otherwise good. In the cotton waste shops, because of the nature of the work, it was said that the girls were obliged to stand from 6.30 to 11.50 A.M. and from 12.45 to 6 P.M. One minor having Pott's disease was found working in a well-conducted handkerchief factory. Several small, undersized but healthy appearing minors were found in a cotton yarn mill. Their size was so unusually small as to give rise to the suspicion that the certificates which they presented as to their age were incorrect. As a rule, however, the minors appeared healthy and the conditions under which they worked were good.

Horse blankets: 4 girls and 1 boy, all healthy, were found to be working under satisfactory conditions.

Shoddy: 5 minors, all males, were found in the 5 shoddy mills visited. One who was healthy worked in a mill in which the conditions as to cleanliness were moderately bad throughout. In the other mill, 4 healthy boys worked in the carding room under fairly good conditions.

Silk cloth: 6 minors who appeared healthy, and who were found to be working under good sanitary surroundings, were observed in the one factory visited.

Woolens: cloths and yarns, — 9 mills were visited, in which were observed 46 male and 52 female minors, — a total of 98. No minor was found to be diseased. In 1 mill the conditions were observed as only fair, owing to the fact that the buildings were very old. The sanitary conditions in the main were good, although in 1 establishment the light in the dyehouse was bad. The minors as a class were rather above the average. Felts, — 31 males and 17 females comprised the 48 minors who were found in mills which made felts, — 4 in number. In the carding

room of 1 factory 3 male minors who appeared healthy worked under distinctly unsanitary conditions, in that the air was thick with cotton dust. The operatives, including the minors, were covered with the "fly," as were also the floors, walls, ceilings, machines and belts. The employer had discontinued the use of a fan in this room, on the theory that the fan caused the loss of too much cotton. In another cotton mill was found 1 minor who had valvular disease of the heart. He was working under good conditions, and was cognizant of his disease, as were also his parents. Six minors working in the carding room were exposed to a moderate amount of dust, not excessive. All were healthy. One minor in the carbonizing room was exposed to weak fumes from sulphuric acid. The ventilation was adequate.

Wire and Cable (Insulated). — In the 1 factory visited all the minors were found healthy and working under good conditions.

Wire Window Screens. — Four male minors, all healthy, worked under good conditions.

Woodworking. — Pianos: the 1 minor found working at the trade of piano making appeared healthy and was working under good conditions.

Shoe heels: in the manufacture of celluloid-covered wooden heels 17 minors were found, 7 of whom were males and 10 females. All of these appeared to be healthy. Although the buildings were old and the floors oil stained, the general cleanliness was good. The minors were exposed to the odor of cement, although "deodorized" cement was used; and to the odor of wood alcohol used in softening the celluloid. The faces of the girls who worked on the polishing machines which "rubbed" the heels after they had been blacked were somewhat covered with blacking, notwithstanding the fact that the polishing wheels were provided with hoods and exhausts.

Shoe lasts: 2 healthy male minors in the 1 factory visited were working under good conditions; and, although much dust was created by the woodworking machines, the minors were not exposed to it, owing to the effective system of dust appliances in use.

Industrial Hygiene. The Relation of Industries, Processes, or Unhygienic Conditions, to Health.

Manufacture of Aluminum Goods. — In the manufacture of aluminum goods considerable lacquer is used, which, while offensive, appears to be considered not especially injurious to the health of those who use it. Cough and headache are symptoms not infrequently met with by beginners. Those inured to its use claim no ill effects.

Proper appliances are necessary in this industry for the removal of dust from polishing wheels and acid fumes from dipping benches.

Chocolate and Cocoa. — While the grinding of the cocoa beans and of sugar causes considerable cocoa and sugar dust, there appear to be no intrinsically objectionable features connected with this business.

Manufacture of Colors and Gums. — Those working at the making of gums for use in the textile industries are exposed to vast amounts of starch dust. No feasible method of controlling this dust has yet presented itself.

Manufacture of Crucibles (Plumbago Products). — Dust from grinding plumbago and from grinding old crucibles are inherent dangers of this trade.

The men working at moulding the plumbago "mud" are sometimes affected by skin eruptions on the hands.

Manufacture of Curled Hair. — Four cases of malignant pustule, of which 3 were so proved by bacteriological examinations, were known to have occurred at 1 shop in a period covering some seven years. Prolonged fumigations of the hair by means of formaldehyde gas followed by boiling the hair have apparently done away with this disease at this shop, as no case has been reported in the past three years.

Manufacture of Cutlery. — Dust from the large emery polishing wheels and from the wood polishing wheels when used to polish wooden handles furnishes the element of danger to health in this trade. Proper protection is easily possible.

Manufacture of Foundry Products. — The light is apt to be poor in foundries, except of modern types. Most adequate ventilation is of the utmost importance, especially in foundries making castings from metals such as brass and copper, which give forth noxious vapors. The cleaning of castings develops dust from emery wheels, from tumbling machines, from revolving wire brushes, from flexible shafts and in great amounts from sand blasts. Acid fumes from cleaning castings by pickling with vitriol also adds its share of danger. All of these objectionable features were prevented in many instances by the use of proper appliances. In foundries adjacent to some system of sewerage a proper washroom and water-closets are required by law. Where such are not provided in foundries in the smaller towns, it is the custom for the men to wash from buckets on the floor of the foundry room.

Manufacture of Japanned or Patent Leather. — Good light and adequate ventilation are especially necessary in this trade, which may properly be classed as dangerous. The dangerous element lies principally in the use of naphtha. In one of the two factories visited the odor of naphtha was noticeable in every department. "Naphtha drunks" were said to be not uncommon among the workers. The minors at work were all Italians, young and rugged, recently landed, so that the occupation had not as yet affected them. In the room where the japan was painted on the hides, it was the custom for the men to work with all clothing removed except their trousers, not because of the heat, which was considerable, but because it was easier to clean their bodies than their clothes.

Manufacture of Jewelry. — Adequate ventilation and good light are highly desirable in this trade. The processes which need safeguarding are (1) dust arising from buffing wheels made from cotton rags, and (2) acid fumes arising from acid-dipping benches in coloring rooms. Proper appliances were almost universally found to be provided for the protection of the employees. A common custom in the shops which might be injurious in its effects upon health was that of leaving uncovered, in workrooms, weak solutions of cyanide of potassium. Not infrequently the rooms were found to be overheated. In the process of refining gold and silver there was observed to be a source of dust from grinding and sifting ashes. Two kinds of grinder are

commonly used: the so-called pan grinder, which gives rise to a large amount of dust; and the circular rotating grinder which is practically dust tight. In one instance a pan grinder was found to be fitted with a hood and exhaust which gave considerable, although not complete, protection.

Machine Shops. — Many of the machine shops have foundries attached. Of the peculiar dangers of these latter we have already spoken. Machine shops are apt to be dark, on account of the machinery present; the floors are apt to be darkened by oil, and there is usually more or less tobacco sputum upon the floors. Dust may be scattered from emery wheels, which are usually present, unless proper appliances are provided.

Manufacture of Oil Cloth. — The manufacture of oil cloth, although perhaps not a dangerous trade, may be said to be dirty and generally unattractive. In one of the two factories visited, and to a lesser extent in the other, the window glass was observed to be covered with a dark, yellow, hardened, varnish-like oil, which darkened the workrooms materially. The odor of boiled oil permeated the factory and the surrounding outside air for considerable distances. The work is hard, and no minors were found employed directly at this trade.

Manufacture of Pearl Goods. — In this industry, which is intrinsically injurious or dangerous to health, a vast amount of fine pearl dust is generated by different processes; but in the best shop, which provided all its machines with hoods and exhaust blowers and fans, no appreciable amount of pearl dust was detected in the air of the room. The hands, and often faces, of the workers appeared to be white with the dust. It seemed to the State Inspector of Health that minors should be excluded from this trade.

Manufacture of Rubber Goods. — The intrinsic dangers in this industry are from fumes of naphtha used in the cement, and from the chemicals used in milling or mixing the rubber, such as litharge. A danger to minors was found in a rubberized clothing factory, in that they were obliged as a part of their duty to work under hot machines, in a doubled-up posture, breathing overheated air vitiated by naphtha fumes. These boys were called "spreader-helpers," who assist in the process of spreading rubber on cloth.

Manufacture of Boots and Shoes. — The dangers from inhaled naphtha used in the cements, the liability to inhale dust from the various leather-working machines, the tendency to overcrowd and overheat the workrooms, are to be safeguarded in this trade. No injurious process is such that proper and reasonable care may not do away with its danger in this industry. Good light and adequate ventilation are prerequisite.

Manufacture of Shoe Laces. — In the manufacture of shoe laces mercerized cotton thread, dyed black, is used, from which some "fly" escapes and causes the floors to appear dirty. The braiding machines are very noisy, and, being dark, affect unfavorably the light in the workrooms, which also are apt to be overheated. The dressing room, in which starch paste is applied to the thread and later dried, is commonly kept at a uniform temperature of 110°. The excessive heat, together with the disagreeable odor from the paste, makes the conditions in this room, to say the least, unattractive.

Manufacture of Silverware. — The dangers of this trade, intrinsic or other-

wise, were seen in the largest shops visited. Some of them are connected with the following processes: brass and iron casting; refining of gold and silver; buffing on rag wheels; plating and sand buffing. This latter process is extremely dirty and unattractive. Metals are polished on a wheel made of walrus hide by means of a mixture of sand and pumice, and it is claimed that an exhaust fan cannot be used to take away the dust, inasmuch as it would remove all the pumice. Some of the wheels used in the process of sand buffing were observed to have wooden half covers, which kept most of the dust from the room; but the men's faces and arms were black with the dirt, so that some must inevitably have been inhaled. Sand buffing on nickeled silver is very laborious, and none but rugged fellows can do the work.

Straw Hats. — The main unhygienic conditions observed in this work were: (1) the tendency to overcrowd and overheat sewing rooms where women and girls were employed; (2) steam in the pressing rooms; (3) the heat and general untidiness of the sizing room; and (4) the dust from pouncing machines used on felt hats. It was noted that denatured alcohol has replaced wood alcohol in the manufacture of straw hats in this district.

Woodworking. — Shoe heels: the workers herein are exposed to wood dust from polishing and cutting machines, to leather dust, to fumes of naphtha and of wood alcohol used in working celluloid. In the one factory of this kind visited, wooden heels were covered with celluloid, silk, canvas, leather or cloth of different kinds. Proper appliances were provided for all machines making dust, and the ventilation was adequate.

Shoe lasts: turning, cutting, trimming and polishing lasts made from wood give rise to large amounts of wood dust, which, in the one shop seen, was adequately removed by an excellent system of hoods and exhausts.

Health District No. 5.

Harry Linenthal, M.D., *Roxbury, State Inspector of Health.*

This district includes Suffolk County.

The work in general consisted of the inspection, licensing and supervision of tenement workrooms; inspection of factories and workshops where clothing is manufactured; inspection of cigar factories; inspection of a few candy factories and other manufacturing establishments; the investigation of local nuisances and complaints relative to manufacturing and mercantile establishments; investigation of outbreaks of diseases dangerous to public health; examination of minors in factories; and special work assigned by the State Board of Health.

I. Hygiene of Tenement Workrooms.
   1. Overcrowding.
   2. Long Hours of Work and Employment of Minors.
   3. Communicable Diseases.
   4. Other Industries in Tenement Workrooms.
   5. Difficulty of Supervision of Tenement Workrooms.
   6. Complaints investigated in Connection with Tenement Workrooms, and Prosecution of One Case.

I. Hygiene of Tenement Workrooms.

1. Overcrowding. — The work on wearing apparel in tenement workrooms in the congested tenement district is generally done in a room which serves as workroom, living room, dining room and kitchen. In the evening, when all the inmates come together, this room is overcrowded, and the finished garments are not infrequently taken into the bedroom and placed upon the bed, which is often unclean. The New York law governing tenement workrooms reads: "No room or apartment in a tenement or dwelling house used for eating or sleeping purposes shall be used for the manufacture . . . of coats, vests, trousers," etc. The adoption of such a law in this State would undoubtedly improve conditions, inasmuch as it would do away entirely with the tenement workrooms in the congested district. Manufacturers, however, with whom this matter was discussed, maintained that such a measure would completely drive the clothing industry from Massachusetts.

2. Long Hours of Work and Employment of Minors. — The hours of work cannot be regulated in tenement workrooms. Many of the women work excessively long hours, and the amount they do is regulated only by the quantity they can get and by their physical endurance; they are particularly overworked in the busy season, when the employer is rushing the work. In many instances an outside finisher does twice the amount done by the finisher in the shop, for not only do they work long hours, but in the evening other members of the family are drafted into service.

Only in two instances were minors found working in tenement workrooms, and this was during the summer, when the schools were closed.

3. Communicable Diseases. — A great deal of attention has been given to the occurrence of diseases dangerous to public health in tenement workrooms. Every case of such disease reported from a tenement workroom was investigated, and, if occasion demanded, the license was revoked. If any clothing was found on the premises which had been exposed to infec-

tion, the local board of health was notified to issue such orders as public safety might require. In spite of these measures the public is not properly protected against the spread of contagious diseases because of unreported cases. This lack of protection is especially noticeable in cases of tuberculosis. New tenants move into premises recently vacated by tubercular patients; the premises may not be disinfected, and later a license for work on wearing apparel may be obtained in these premises. In every instance where the removal of a patient ill with tuberculosis was discovered, the local health authorities were notified. Forty such reports were received from private sanatoria, giving the addresses of tubercular patients recently admitted. In each instance the local board of health was notified, and the premises recently vacated by the patients disinfected. Twelve other instances of the removal of tubercular cases were called to the attention of the local board of health and the premises disinfected; 2 of the premises were in Chelsea and 10 in Boston.

Nor is the public sufficiently protected against the spread of contagious skin diseases by means of clothing made in tenement workrooms. Such diseases as scabies, impetigo contagiosa and pediculosis are quite common in the congested districts; but since these cases are not reported, their existence can only be discovered accidentally in the course of inspection. In one tenement, for example, an infant about a year old, with discharging pustules and moist, dirty yellow crusts on his head, face and neck, — a severe, neglected case of impetigo contagiosa, — was found in the room where the mother was finishing pants. Several pairs of unfinished trousers were found on the baby's crib, which, it is more than probable, had been brought in contact with the contagion. In another tenement workroom a child with pronounced scabies was found. In both cases the licenses were revoked, and the clothing held until it could be disinfected by the Boston board of health. In several instances licenses were refused because of contagious skin diseases, including impetigo contagiosa, scabies and pediculosis capitis.

4. Other Industries in Tenement Workrooms. — Work on wearing apparel is not the only industry carried on in tenement workrooms. A number of other industries, for which at present no license is required, are carried on in these homes. Among these may be mentioned the manufacture of paper boxes, artificial flowers, baseballs, cigars and cigarettes, tooth brushes and home laundries. In one house an old Italian was found cracking nuts, to be sold on fruit stands. Such home industries should be included in the provisions of chapter 106, section 56, Revised Laws, inasmuch as there is just as great a danger of disseminating infection by means of these articles as there is by means of wearing apparel.

5. Difficulty of Supervision of Tenement Workrooms. — Some difficulty was found in keeping track of tenement workers, who move frequently. A tenement worker may move away without surrendering the license or without giving notice of her removal, and continue to do the work on the

new premises. The employer may not be aware that the worker changed her residence.

6. Complaints investigated in Connection with Tenement Workrooms, and Prosecution of One Case. — Six complaints of violation of the law in regard to tenement workrooms were received and investigated. One man was found working for private individuals, who ordered their garments from him. In three cases the complaints were groundless. One case was ordered to stop work at once, and the offence was not repeated.

In another case it was found that the employer was giving out work to a woman who lived in two rooms in a basement where the conditions were unsanitary, and to whom no license had been issued. The case was brought to court Nov. 6, 1907, and Judge Murray ruled that there was not sufficient evidence to show that the man "hired, employed or contracted" with this woman to do this work.

II. Hygiene of Factories and Workshops where Clothing is manufactured.

Having become familiar with the conditions under which clothing is manufactured in the tenement workrooms, the next step was to investigate conditions under which clothing is made in the workshops and factories. The establishments visited may for the purposes of description be roughly divided into four classes: 1. The manufacture of men's ready-made clothing; 2. The manufacture of men's custom-made clothing; 3. The manufacture of ladies' garments for retail trade; 4. The manufacture of ladies' garments for wholesale trade.

1. Manufacture of Men's Ready-made Clothing. — The factories where men's ready-made clothing is manufactured are for the most part to be found in neglected buildings, where it is difficult to maintain proper sanitation. The stairs and hallways were as a rule found to be dirty, and in many cases the water-closets were foul and filthy. The interior of these establishments was found unclean, the dirty walls and ceilings appeared not to have received a coat of whitewash for years, and the windows were often so dusty as to be almost opaque. The disgusting and dangerous habit of spitting on the floor was observed in almost every establishment visited. This habit is rendered especially dangerous by the fact that the garments, in the process of manufacture, are thrown on the floor, and the dried as well as the moist sputum may thus be freely circulated among the operatives by the contaminated clothing. In several instances the State Inspector of Health was told that the employees did not spit on the floor, but on heaps of rags in the corners. Investigation showed that these rags were sorted by hand in the rag shops.

a. Tuberculosis in Tailor Shops. — The sedentary nature of the work, the unsanitary conditions of the workshops, and the congested tenement districts tend to reduce the vitality of the workers. These factors, combined with the low wage rate received for their work, and the consequent ill nutrition, render the workers an easy prey to tuberculous infection. Information was

obtained of 5 cases of tuberculosis in tailor shops. All the cases were investigated, and in accordance with chapter 106, section 57, Revised Laws, were reported to the State Board of Health. One individual in a very advanced stage of the disease returned to Russia; 2 were persuaded to give up their work and place themselves under treatment in one of the tuberculosis clinics in Boston; 2 others continue at their work, but are also under care, and are taking all necessary precautions against infecting their fellow workers. These cases, however, are but a very small portion of the actual number of persons so afflicted who keep at work without any supervision, and without instructions as to how to guard against the spread of the disease. The safety of persons employed in factories and workshops, as well as the safety of the public, demands that some system be adopted whereby persons ill with tuberculosis can be supervised at their work, and instructed as to what precautions should be taken against the spread of the disease.

b. Educational Work. — In addition to issuing orders requesting compliance with the statutes, it was thought desirable and necessary to educate as far as possible the employers and employees to a higher standard of cleanliness. The employer of every establishment visited was spoken to at great length, and the importance of better sanitary conditions for his own health as well as for the health of his employees was pointed out. On one occasion an address was made to representatives of all the unions in the clothing industry at a special meeting called for that purpose. The meaning of the health laws was explained to them, and the danger to health from some of the unsanitary conditions was pointed out. On another occasion a similar address was made to an association of manufacturers at one of their regular meetings. Thus efforts were made to carry on an educational campaign both among employers and operatives for the need of better sanitation.

c. Main Cause of the Unsanitary Conditions in the Clothing Industry. — The root of the evils found in clothing factories lies in the contract system, which prevails in the clothing industry. The manufacturer has the goods cut on his own premises, and then turns the material over to the contractors who operate these factories, thus concerning himself but little with the conditions under which the goods are manufactured. The competition among the contractors is extremely keen; they earn a mere pittance, — often less than their employees. In this struggle to eke out a mere existence it can hardly be expected that much attention will be given to matters of sanitation. In striking contrast to the condition of the tailor shops described above are several shops in Boston which are operated not by the contractors, but by the manufacturers on their own premises. These shops are in excellent condition in every respect. To change radically the existing conditions, there will have to be a shifting of the responsibility from the contractor to the wholesale manufacturer. To stimulate the interest of the wholesale manufacturer and have him exert his influence toward improving the existing conditions, the following letter was written by the State Inspector of Health, and addressed to 24 firms: —

Within the last few months I have been carrying on an investigation of the conditions under which clothing is manufactured in this city. I find them a good deal worse than what could reasonably be demanded or expected. Many of the shops are operated in old, neglected buildings, where a high standard of sanitation cannot be maintained. These conditions are unnecessarily made worse by the slovenly and uncleanly habits of the contractors, as well as their employees. Dirt, dust, rags and other refuse are allowed to accumulate in the corners of the shops and under the tables, and conditions are thus created which are prejudicial to the health of the workers, as well as of the public.

The indifference of most employers to the sanitary conditions of their premises is striking. "What do you expect, — this is not a parlor or a ballroom." "Of course they spit on the floor; where do you expect them to spit, — in their pockets?" "What do you want us to make, — parlors of our workshops?" Such remarks and others of a similar nature indicate the attitude taken by many of the contractors, that filth is a natural and necessary condition, and that it is unreasonable to expect a higher standard of cleanliness.

By some employers I am told that the workmen never spit on the floor, but in the corners on heaps of rags, and that "the rags are removed from the shop at frequent intervals." On investigation, I find that the rag men have to handle and sort by hand the contaminated rags.

Visits to several shops, which are operated under exactly similar conditions but which are kept very clean, due to a little effort and attention on the part of the employer, have convinced me that a higher standard of cleanliness can be reasonably expected, and that it should be insisted upon.

With few exceptions, the uncleanly and dangerous habit of spitting on the floor has been observed in every shop visited. In several of these shops persons were found to be ill with consumption. In such cases, the dry, germ-laden sputum is pulverized into dust, and is continually swept through the air of the workroom by the garments thrown on the floor; the disease may be thus conveyed to others.

The law requires that all workshops shall be provided with proper sputum receptacles, and employers who have failed to meet this requirement have been ordered to provide such receptacles at once.

The law further requires that workshops shall be well ventilated and kept clean; and one of my duties as State Inspector of Health is to notify the State Board of Health of all evidences of infectious disease, in order that said Board may request the local health authority to examine such places, and to issue such orders as the public safety may require relative to any unhealthy conditions found therein, under penalty of a fine of not less than $50 for violating the same.

Representatives of the manufacturers, however, visit these shops far more frequently than can be done by the State Inspector of Health. They are thus in a position to maintain a constant supervision over the workshops, and emphatic demands from them that the shops be kept clean, on the penalty of having the work withdrawn, would be very effective.

Several of the manufacturers, whom I have approached on the matter, have manifested a great willingness to co-operate with the health authorities, inasmuch as they believe it to be for their interest to have clothing manufactured under such conditions as will not only put a stop to the spread of tuberculosis, but also of all other contagious diseases which may be conveyed through clothing.

I should be very glad to see you, if you so desired, to talk over with you some plans which might be undertaken to promote better sanitary conditions in the manufacture of clothing.

Hoping that this matter will receive your attention, and that I shall be favored with a reply, I remain

Very truly yours,

(Signed) H. LINENTHAL.

Eight firms replied to the letter, and manifested an interest in improving conditions. The president of the Wholesale Clothiers' Association took the matter up, intending to call a special meeting of his association to discuss means of improving the sanitary standards of the tailor shops, but as there has not been much work, it was thought advisable to postpone action until the shops are running at full time.

2. *Manufacture of Custom-made Clothing.* — The shops where the custom work is done are as a class in even worse sanitary condition than the factories described. They are small, extremely filthy, and most of them are located in very old and neglected buildings. In some instances, in addition to issuing orders for improved sanitary condition to the proprietors of the shops, it was found necessary to apply to the owners of the buildings for changes on the premises and for the provision of sufficient and proper toilet facilities.

3. *Manufacture of Ladies' Garments for Retail Trade.* — Overcrowding, poor light and ventilation, poor and insufficient toilet facilities, are the conditions one meets in this class of workshops. These establishments are situated in the north and west end of Boston, in streets formerly residential, but which have within the last ten years become business streets. As a result of this change the street floors of the tenements in the district have been converted into business places. It is in such quarters that most of these workshops are situated. The front room is used as a store where the ladies' garments are sold, while the rear rooms are used for the manufacture of these goods. Many of the workrooms face into narrow yards or alleys, and are insufficiently lighted. These rooms are in every way unsuitable for use as workrooms, — a use for which they were never intended. The toilet facilities are inadequate. Very rarely are separate closets provided for the sexes, though when asked about it the operatives stated that the closet upstairs or in the next house was used by the men. In one instance the men's closet was several houses away from the building.

The problem as to how to remedy conditions in this class of workrooms was found to be a very difficult one; it was hard to see in many instances how ventilation, light and toilet facilities could be improved upon.

4. *Manufacture of Ladies' Garments for Wholesale Trade.* — The factories where ladies' garments are manufactured for the wholesale trade are in the main located in modern buildings, are as a rule well lighted and well ventilated, and are kept fairly clean.

5. *Compliance with Orders issued, and Prosecutions.* — On the whole, the compliance with orders was fairly satisfactory. In a large number of factories and workshops many visits were necessary before the desired results were obtained. In 3 cases it was found necessary to institute court proceedings; these cases are as follows: —

Court proceedings were instituted against Jacob L. Wolbarsht, 35 Lowell Street, Boston, on two counts: (1) for not having his clothing factory clean; (2) for not providing sputum receptacles. The case came up before Judge Sullivan on May 7, 1908. The defendant maintained that since the proceedings were instituted all the necessary changes were made. He was convicted, and a fine of $10 was imposed.

Court proceedings were instituted against Frank Demark, 42 Beach Street, Boston, for refusing to provide sputum receptacles. The case came up before Judge Sullivan on Sept. 10, 1908. The defendant was convicted, and a fine of $25 was imposed.

Court proceedings were instituted against Joseph Leventhal, 188 Hanover Street, Boston, on two counts: (1) for not having his clothing factory clean; (2) for not providing sputum receptacles. The case came up before Chief Justice Bolster on Sept. 29, 1908. A conviction was obtained, and a fine of $50 was imposed, — $25 on each count. Payment was suspended for a year, during which time the defendant is on probation.

In cases where more or less extensive changes were necessary, it was found advisable to issue orders to the owners or agents of the buildings, instead of to the occupants, inasmuch as it would have been unreasonable to require occupants to expend considerable sums for the improvement of premises which they hire by the month.

The following changes were made by owners of clothing factories: —

a. Walls and ceilings whitewashed.

b. Broken plaster repaired; walls painted; ceilings whitewashed.

c. Walls and ceilings of 4 factories cleaned and whitewashed.

d. Walls and ceilings whitewashed; water-closets placed in proper condition and properly designated in 5 factories.

e. Three additional water-closets installed in building.

f. Closets thoroughly cleaned and plumbing put in repair; broken plaster repaired; walls and ceilings whitewashed.

g. One additional closet installed in each of 3 factories; walls and ceilings of 1 workshop whitewashed; 1 old closet provided with new plumbing; all the halls in the 3 factories replastered and whitewashed, and the stairs cleaned and repaired.

h. Walls and ceilings of hallways in 2 buildings whitewashed; better light provided; water-closets put in good repair; courtyard thoroughly cleaned. Walls and ceilings of another shop thoroughly cleaned, — walls painted, ceilings whitewashed, water-closets cleaned.

i. A new water-closet in process of construction at the time of last visit.

6. *Registration of Workshops and Factories.* — To insure a systematic inspection of workshops and factories, they should be required to register. The smaller workshops and factories move frequently, and such registration is essential if supervision is to be constant.

TENEMENT WORKROOM, WHERE CONDITIONS ARE REASONABLY GOOD. THE ROOM IS LARGE, LIGHT, WELL VENTILATED AND CLEAN.

TENEMENT WORKROOM, WHERE CONDITIONS ARE BAD. THE ROOM IS SMALL AND DARK, AND THE WINDOWS OPEN INTO A NARROW, DIRTY COURT.

TENEMENT WORKROOM, WHERE CONDITIONS ARE DISTINCTLY BAD. THE ROOM IS SMALL, DARK AND DIRTY, AND THE WINDOW OPENS INTO A NARROW, DIRTY COURT.

TENEMENT WORKROOM, WHERE CONDITIONS ARE BAD. THE ROOM IS SMALL AND DARK, AND THE WINDOWS OPEN INTO A NARROW, DIRTY COURT.

TENEMENT WORKROOM, WHERE CONDITIONS ARE DISTINCTLY BAD. THE ROOM IS SMALL, DARK AND DIRTY, AND THE WINDOW OPENS INTO A NARROW, DIRTY COURT.

FACTORY WORKROOM FOR THE MANUFACTURE OF CLOTHING, WHERE CONDITIONS ARE VERY GOOD. THE ROOM IS HIGH STUDDED, LIGHT AND AIRY, AND IS KEPT CLEAN.

FACTORY WORKROOM FOR THE MANUFACTURE OF CLOTHING, WHERE CONDITIONS ARE VERY GOOD. THE ROOM IS HIGH-STUDDED, LIGHT AND AIRY, AND IS KEPT CLEAN.

WORKSHOP WHERE HIGH-GRADE CUSTOM-MADE CLOTHING IS PRESSED, SHOWING OBJECTIONABLE CONDITIONS FREQUENTLY MET WITH.

III. Hygiene of Cigar Factories.

In investigating conditions in the cigar industry, visits were made to most of the shops in Boston. A number of very small shops, where only one or two people work, were not inspected. Most of the establishments were found to be well lighted and fairly clean; receptacles for expectoration were provided, and there was very little spitting noticed on the floor. As a rule, it was found that each bench had a canvas bag attached to it, into which fragments and scraps of tobacco leaf, produced in the process of cigar making, were thrown. These scraps are sold, and used for the manufacture of pipe tobacco, plug, etc.; it is therefore important that they do not fall on the floor to be swept up with dirt. In spite of these bags, however, considerable tobacco was noticed scattered on the floor in some establishments.

The problem of ventilation of cigar factories is a very difficult one. With rare exceptions all the windows in the workrooms were found closed. This was the case even on warm days. The workmen maintained that it was made necessary by the nature of the work, as "too much air would dry the tobacco leaf." The employers, on the other hand, maintained that it was not necessary to have the rooms so air tight, but stated that they could not remedy conditions, — that the workers refused to work if the windows were opened. The result was that the rooms were hot and stuffy, and this condition was made still worse when the gas was lighted in the workrooms in the late afternoon hours.

The objectionable habit of biting off the end of the filler and inner wrapper, and finishing the cigar by the aid of saliva, was noticed to a greater or less extent in every establishment visited. It was felt that an appeal both to employers and employees to improve ventilation and to eradicate the revolting habit of the use of saliva in finishing the cigar would result in some improvement. The following letters, written by the State Inspector of Health, were addressed, the first one to 18 firms and the second one to the Cigar Makers' Union: —

GENTLEMEN: — A recent investigation of sanitary conditions of cigar factories in this city revealed objectionable conditions and practices in most of the establishments visited. Among these were the inadequate ventilation of the factories, and the revolting habit, observed to a greater or less extent in all factories, of biting off the end of the filler and inner wrapper, and finishing the cigars with the aid of saliva.

While most of the establishments have a large number of windows through which adequate natural ventilation might be obtained, the windows are kept closed because of the alleged reason that the tobacco leaves would dry quickly if the windows were open, and because some of the workers are afraid of "catching cold" from open windows. The result is, therefore, that the air in most of the workrooms is so vitiated as to be injurious to the health of the operatives.

Inasmuch as it is a matter of concern to employers that men who work in stuffy rooms are not such efficient workers as those who work in well-aired rooms,

several of the manufacturers have expressed themselves as being anxious to adopt the following measures, which they believe to be practical: —

1. All the windows in the factories should be opened every morning for ten or fifteen minutes before work begins.

2. All the windows should be thrown wide open for at least twenty minutes or half an hour during the noon hour.

The workrooms will thus be flushed with fresh air twice during the day, which will undoubtedly improve conditions.

As regards the filthy practices referred to, the manufacturer has it in his power to demand and insist that his goods be made in a clean way. I have observed in the course of my inspection that in those establishments where the manufacturers took a decided stand on the matter, these nauseous practices were at a minimum; whereas in the establishments where the manufacturer was indifferent, the practice was general. I would suggest, therefore, that a determined effort be made by you to eradicate habits which are not only disgusting, but which may be factors in the spread of contagious disease. Notices should be posted in your factory, stating that in the interest of public health and decency such practices will not be tolerated.

Please acknowledge the receipt of this letter, and inform me what action you intend to take in the matter.

Very truly yours,

(Signed) H. Linenthal.

To the Officers and Members of Union 97, Cigar Makers' International Union, 11 Appleton Street, Boston, Mass.

Gentlemen: — A recent investigation of the sanitary conditions of cigar factories in this city revealed objectionable conditions and practices in most of the establishments visited. Among these were the inadequate ventilation of the factories, and the revolting habit, observed to a greater or less extent in all factories, of biting off the end of the filler and inner wrapper, and finishing the cigars with the aid of saliva.

While most of the establishments have a large number of windows through which adequate natural ventilation might be obtained, the windows are kept closed even in warm weather, because of the alleged reason that the tobacco leaves would dry quickly if the windows were open, and because some of the workers are afraid of "catching cold." The result is, therefore, that the air in most of the workrooms is so vitiated as to be injurious to the health of the operatives.

From figures of the United States government census it appears that, next to stone cutters, cigar makers head the list in the rate of those who die from tuberculosis. The poorly ventilated workrooms and the irritating tobacco dust are undoubtedly the main factors in causing this high death rate from consumption among the members of your trade. From observations in the course of my inspection I am convinced that your trade does not demand air-tight rooms. In several factories I found windows open without injury to the tobacco leaf, which was kept from drying by a damp cloth. I have written to many of the manufacturers, requesting them to have all the windows in the factory wide open for about ten or fifteen minutes before work begins in the morning, and for about twenty minutes during the dinner hour.

Your secretary informs me that it is the function of your union to adopt measures looking to the health of its members, as much as it is to concern itself with wage rate, hours of labor, etc. It is therefore incumbent upon you to see

that any practical measures looking to the improvement of the present unsanitary conditions be carried out, and to instruct your members to that effect.

As regards the filthy practices referred to, it is your duty to eradicate them, for they are not only disgusting, but are likely factors in the spread of contagious disease. Your union label, you assure the public, stands for cleanliness of production. The public has, therefore, a right to demand and expect a clean product.

Now that these matters have been brought to your attention, I shall expect your organization to take a firm stand in the interest of public health and decency.

I will ask you to be good enough to acknowledge the receipt of this letter, and to inform me what action you propose to take.

Very truly yours,

(Signed) H. Linenthal.

Answers were received from all but 3 firms, each expressing a readiness to carry out suggestions, and assuring co-operation in improving conditions.

The Cigar Makers' Union, in issuing a call for their next regular meeting after receipt of the letter, announced that the special question of sanitation of cigar factories was to come before the meeting. An order was passed by the union prohibiting the practice referred to in the letter. Each member was later notified of the order.

Several cigarette factories visited were all found to be adequately lighted and ventilated, and very clean. In one instance there was only one closet for both male and female employees, and an order for the provision of separate closets for the sexes was issued. The proprietor, however, requested an extension of time before complying with this order, as he expected to vacate the quarters within a very short time.

IV. Hygiene of Candy Factories and Other Manufacturing Establishments.

A systematic inspection was begun of the candy factories, but only 11 were visited. In the main these were found fairly well lighted and ventilated, and the larger factories were fairly clean. In several of the smaller places the standard of cleanliness was not so good, and orders for higher standards were issued. In a few factories separate dining rooms were provided for the employees.

During the year a number of other manufacturing establishments were visited because of some complaint that had been received concerning them. Among these were: —

a. A printing establishment. This place was found in excellent condition, well lighted and well ventilated; receptacles for sputum were provided for the employees, and also notices were found posted, stating that employees spitting on the floor will be discharged. The toilet facilities were found to be very good.

b. A modern building. The factory was well lighted and well ventilated. All the machinery causing dust, such as emery, polishing and buffing wheels, was equipped with hoods and suction pipes. A small hospital room with three beds was maintained on the premises, and a trained nurse was in constant attendance.

c. One of the largest shoe factories in the country, employing about 3,500 people. Sanitary conditions were found fairly satisfactory. The removal of dust was efficient. A physician was on the premises all the time. Among some of the other features of this factory were bowling alleys, a billiard room, recreation room, and a library containing a large number of periodicals and about 600 volumes.

d. A rubber factory. The conditions as to light and ventilation were fairly satisfactory. A great deal of soapstone dust was found in the dust room, where the goods were covered with soapstone before being vulcanized. There did not seem to be any practical way of removing the dust. The grinding and buffing wheels were protected with hoods and exhaust fans. Some of the finished products were boiled in a potash solution. This boiler was not protected by a hood to carry off the fumes. The water-closet accommodations were not sufficient, and in some parts of the factory there was evidence of expectoration. In compliance with orders issued, five additional water-closets were installed and sputum receptacles were provided where needed.

Two establishments in Boston where felt hats are manufactured were visited. In 1, no provisions existed for carrying off the steam vapor from the "sizing" room. Upon orders issued, hoods to carry off the steam were installed.

Two brush factories were inspected. The dust-removal appliances were found satisfactory in both. Receptacles for sputum were installed, and in one of the factories several of the rooms were cleaned and whitewashed in compliance with an order issued.

Three chair factories were visited. In 1, no provisions were found for the removal of dust. The planing and sandpapering machines were found to give rise to a great deal of very fine dust. The floor and the objects around the machine were thickly covered with this dust. The proprietor stated that it would cost about $2,800 to install an effective dust-removal system, and for that reason he was going to vacate these premises in a month or two and move into a building equipped with such appliances. In the other 2 factories the removal of dust was fairly satisfactory.

Seven other manufacturing establishments were visited. In 3, orders were issued for the first-aid outfit. These outfits were installed. In 1 blacksmith shop the ventilation was found inadequate; work was already begun with a view to improving it.

V. Numerical Data.

Total number of visits to tenement workrooms,	1,524
Number of licenses granted,	644
Number of licenses granted (application),	118
Number of licenses refused,	117
Number of licenses revoked,	132
Not found,	219
Not in,	38
Reinspected,	506
Total number of contagious diseases investigated in tenement workrooms,	95

Of the licenses revoked, 72 were revoked on account of contagious diseases, as follows: —

Measles,	23
Scarlet fever,	17
Diphtheria,	13
Croup,	1
Whooping cough,	3
Tuberculosis,	7
Typhoid fever,	3
Chicken pox,	1
Impetigo contagiosa,	1
Cerebro-spinal meningitis,	2
Scabies,	1

Total number of visits made to factories and workshops,		725
Number of first inspections made,		387
Clothing factories and workshops,	321	
Cigar factories,	31	
Candy factories,	11	
Other manufacturing establishments,	17	
Not found by addresses obtained,	7	
Number reinspected,		338
Total number of orders issued,		520
Lighting,	2	
Ventilation,	4	
Hooding steam boilers,	1	
Cleansing,	159	
Whitewashing and repairing,	56	
Additional closets,	10	
Designation of closets,	20	
Sputum receptacles,	261	
Proper receptacles for handling chocolate,	2	
First-aid outfit,	5	
Total number of orders complied with,		371
Lighting,	1	
Ventilation,	1	
Hooding steam boilers,	1	
Cleansing,	126	
Whitewashing and repairing,	52	
Additional closets,	10	
Designation of closets,	13	
Sputum receptacles,	162	
First-aid outfit,	5	

VI. Examination of Minors in Factories.

It is to be regretted that, on account of the time necessarily spent investigating clothing workshops and tenement workrooms, so little attention could be given to the examination of minors in factories. In only 1 factory was

a systematic examination of the minors made. Of the 154 minors seen and questioned, 14 of the 17 found in ill health were examined physically. Of 5 minors giving a tubercular family history, 3 were found not to have any signs of the disease. Two others had suspicious signs in the chest, but the conditions under which they were examined were unfavorable. Letters were written to the parents of these minors, calling their attention to the condition of the minors, with the suggestion in each case that the minor come to the inspector's office for a more thorough examination; but none came.

Twelve minors were found to be anæmic and ill nourished. One had cervical adenitis, 1 purulent rhinitis and pharyngitis, and 1 bronchitis.

VII. Investigation of Communicable Diseases.

In addition to the investigation of communicable diseases in connection with tenement workrooms referred to above, the following investigations were made: —

An outbreak of scarlet fever in Revere was investigated and reported upon in February.

An outbreak reported as scarlet fever was investigated in Winthrop and reported upon in April.

Daily reports were submitted on the investigation of the typhoid fever outbreak in Jamaica Plain.

On May 28 an investigation was made of a case of scarlet fever in Chelsea, which was released from quarantine while the patient was still freely desquamating. Upon request made to the Chelsea board of health, the case was isolated and the house placarded until the desquamation ceased.

VIII. Local Nuisances.

Conditions found.	*Action taken.*
On Dec. 14, 1907, the attention of the Revere board of health was called to a nuisance consisting of an overflowing cesspool on Adams Street, Revere.	Cesspool cleaned out. Nuisance abated.
On Aug. 26, 1908, the attention of the Revere board of health was called to a nuisance consisting of an overflowing cesspool on Beachland Avenue, Revere.	Cesspool cleaned out; new cesspool constructed. Nuisance abated.
On April 3, 1908, the attention of the Chelsea board of health was called to a nuisance consisting of exposed heaps of rags on Second Street, Chelsea.	Rags removed.
On May 19, 1908, the attention of the Chelsea board of health was called to conditions of overcrowding found in certain districts in Chelsea.	One house was ordered to be vacated; many tenants were ordered to move. Conditions improved.

A number of complaints received from various sources were investigated. A nuisance existing in a factory building on Richmond Street, consisting

of foul odors due to the storage of herrings in the basement, was investigated. A letter was written to the owner of the building, suggesting that he take steps to remedy the conditions. The herrings were removed and the nuisance abated.

On July 6, 1908, a restaurant in Boston was inspected because of a complaint received that the waitresses were not allowed to sit down during working hours. A letter was sent to the proprietor, calling his attention to chapter 106, section 41, Revised Laws.

On May 29, 1908, an inspection was made because of a complaint received that one room where a number of operatives are employed was very badly ventilated, and that several cases of tuberculosis were reported from that room. The complaint was found groundless. All the rooms were found to be large and effectively ventilated by a very elaborate ventilating system recently installed.

Two other complaints, relative to the conditions of the water-closets in mercantile establishments, were investigated, but were found to be groundless.

Health District No. 6.

Albert P. Norris, M.D., *Cambridge, State Inspector of Health.*

This district includes the cities of Cambridge, Everett, Malden, Medford, Melrose and Somerville, and the towns of North Reading, Reading, Stoneham and Wakefield.

The work consisted mainly of the investigation of outbreaks of diseases dangerous to the public health, the inspection of factories and the examination of minors, the inspection of schoolhouses and the investigation of local nuisances.

Diseases Dangerous to the Public Health.

Recommendation was made to the Stoneham board of health that they establish, in conjunction with the neighboring towns, facilities for doing culture work, and that physicians be requested to report promptly all diseases dangerous to the public health.

In January, 1908, some cases of scarlet fever which occurred in Melrose, mainly in the Lincoln School, were investigated.

An outbreak of scarlet fever in Wakefield was investigated. It was found that a mild, unrecognized case was probably the means of infecting 2 adults, both of whom died.

In January, 1908, upon the investigation of a complaint, it was found that a milk dealer in Cambridge was concealing, with the aid of his physician, 2 cases of scarlet fever in his family. The matter was reported to the Cambridge board of health, and both milkman and physician were prosecuted.

In April an investigation was made of about 200 cases of streptococcus infection of the throat and of 46 cases of scarlet fever among Harvard students and 12 cases of scarlet fever outside the college. The cause of the throat infection was found to be in the milk which was furnished to Memorial Hall

in Cambridge. An examination of the sediment of one can showed pus and abundant streptococci.

An outbreak of measles in Wakefield was investigated. Most of the cases were among the Italians in the district, and the outbreak was thought to be caused by a child ill with measles, brought from Boston, who was not properly quarantined.

Twenty-six cases of measles occurred in the Linden Grammar School in Malden. The number of cases rapidly increased, and spread to Somerville and Cambridge. The factors which started and caused the rapid spread of this outbreak were (1) delayed diagnosis, (2) failure to report all the cases, (3) too early release from quarantine.

Upon the request of the Everett board of health 3 cases of suspected smallpox were examined. A similar examination was made at the request of the Melrose board of health. None of the cases examined proved to be smallpox.

An outbreak of typhoid fever along the route of one milkman in North Cambridge and Lexington was investigated. The probable cause of infection was a milk dealer who was washing bottles while attending as a nurse to a typhoid patient.

Four cases of typhoid fever were investigated in North Reading. It was thought that 1 patient in a small cottage conveyed the infection to neighbors, 3 people being sick with the disease.

An investigation of an outbreak of 12 cases of typhoid fever in Everett showed the common source of infection to be a young person ill with typhoid fever whose family furnished milk to the neighborhood. Six other members of his family were infected and came down with the disease. All necessary precautions were taken against the further spread of the disease through the milk.

Recommendations were made by the State Inspector of Health to the Malden board of health to disinfect premises vacated by tubercular patients. An investigation of a bakery in Malden was made where a tubercular person was reported to be employed. The attention of the local board of health was brought to the matter, and the person in question was prevailed upon to change his occupation.

A person ill with tuberculosis, who was reported to be careless in his personal habits, was visited and was instructed as to the care he must exercise and what precautions he must take. Later he was using a spit cup. The conditions at his home were much improved.

Local Nuisances.

The attention of the board of health of Wakefield was called to a nuisance consisting of overcrowding and inadequate toilet facilities in a tenement house in Emerald Street. Attention was likewise called to the pollution of the Saugus River by factory sewage.

The need of a sewer on Washington Street, Stoneham, was urged upon the local board of health. A nuisance caused by an overflowing cesspool was abated.

The pollution of a brook by waste from a tannery was brought to the attention of the Stoneham board of health, and steps were taken at once to remedy the condition.

Factory Hygiene.

During the year 252 factories were inspected. In 120 conditions were found satisfactory. Verbal orders were given to 52 manufacturers calling their attention to 62 objectionable conditions. Letters were written to 77 manufacturers calling their attention to 151 violations of the law. Eighty-eight of the factories were reinspected, and it was found that 163 objectionable conditions were changed in accordance with the verbal and written orders.

Light and Ventilation of Factories and the Removal of Dust. — In most of the factories and workshops visited light and ventilation were found adequate. Nineteen orders or suggestions for improvements were issued, 7 for light and 12 for ventilation. The light was improved in 4 instances and the ventilation in 10. In 1 knitting mill, where an addition to the factory was under construction, it was suggested that certain sewing machines, then in the center of the room, with insufficient light, be placed near the windows when the new addition was occupied. In 1 factory, in compliance with suggestions made, new water-closets were installed in several departments. The existing water-closets and wash rooms were improved, and the windows in one of the rooms were washed.

In a room in a rubber factory where cement was used there was no provision found for the removal of the naphtha fumes. The managers promised to install an exhaust system.

In 1 laundry the ventilators were enlarged and ventilation improved as suggested. In another laundry, where artificial light was used on one floor, the electric incandescent bulbs were in use. A suggestion was made to provide shades to protect the eyes of the operatives.

In 3 press establishments visited considerable artificial lighting was used in the center of large rooms. In 1 it was suggested that a skylight be put in. One mill was found very poorly lighted. Improvements were promised. In 3 factories the windows were cleaned, and thereby light was very much improved.

Suggestion was made to 1 manufacturer to protect six emery wheels with hoods and suction apparatus; to another manufacturer that a suction fan be installed in the cast cleaning room. Both suggestions were complied with. A suggestion was made to 1 manufacturer that a muffler from a gas engine be piped out of doors instead of in the basement, whence the smoke was diffused throughout the building. The suggestion was complied with.

Several factories were found inefficiently equipped with dust-removal devices. Two firms were ordered to install hoods and suction pipes for emery wheels.

In 1 shoe factory it was found that the dust-removal suction pipes threw the dust into the open air, creating a nuisance. Orders were issued for the protection of a marble planer, for the installation of dust-removing devices

in an organ factory, and for the improvement of the dust-removing devices of a carding machine in a mattress factory.

Of 16 orders issued relative to the better protection of employees against dust, 9 were complied with.

In other establishments the following changes were brought about as a result of suggestions made by the State Inspector of Health: ventilation was improved and water-closets kept in better condition; an exhaust fan was installed to remove hot air, caused by Bunsen flames, in a lead factory; an exhaust fan out of repair was replaced; and the acid flues in a jewelry factory were enlarged to improve ventilation of the lacquering department.

Drinking Water. — The water from a well used by a manufacturer in Wakefield was examined, at the suggestion of the State Inspector of Health, and found to be polluted. The employees have since been supplied with town water.

In 1 factory in Stoneham a well was found near water-closets. Suggestions made to the local board of health and to the board of public works resulted in the introduction of town water and sewer connections.

Foundries. — In the 6 foundries visited in the district the light and ventilation were found fairly satisfactory. The dust caused by the sand blast was not adequately removed in most of them.

In 1 foundry it was necessary to order the installation of wash rooms, and in another, improved washing facilities.

Health of Minors in Factories.

Of the 2,453 minors seen and questioned, 89 were found in ill health or physically unfit (43 males, 46 females), 44 of whom were under eighteen years of age. Of this number, symptoms of tuberculosis were detected in 9, and signs indicating the probability of the beginning of this disease in 3. Other conditions of ill health discovered, several of which may have been detected in a single minor, were as follows: bronchitis, 22; valvular heart disease, 18; anæmia, 18; laryngitis, 7; tonsilitis, 2; inflammation of cervical glands, 2; pleurisy, 2; empyema, 1; rheumatism, 1; debility, 4. Among deformities were noted a case of pigeon breast, 1 of hare lip and cleft palate and 1 of wry neck.

In at least 20 instances a change was made in the kind of work done by the minor by calling to the employer's attention the minor's condition.

The Relation of Processes or Unhygienic Conditions to the Health of Minors.

The departments in industries which seemed to the State Inspector of Health to be more or less responsible for the ill health of minors were (1) rattan splitting, which exposed minors to a very fine dust; (2) talc dusting in rubber works; (3) the use of naphtha in rubber cement work; and (4) exposure to fine lead oxide dust in the manufacture of storage battery grids.

Possible unhygienic influences to which minors were exposed were noted

in the following industries: (1) weaving, or winding preparatory to weaving, nets of linen; (2) manufacturing corn brooms; (3) braiding silk; (4) candy making; and (5) jewelry lacquering.

Tenement Hygiene.

One thousand and ninety visits were made to tenement workrooms, and 845 licenses to work on wearing apparel issued. These rooms were found to be clean. In only 4 cases were licenses revoked.

At the suggestion of the State Inspector of Health a knitting mill employing a large number of tenement workers installed a fumigating apparatus to fumigate goods removed from infected tenements or dwellings.

Schoolhouse Hygiene.

Thirteen schoolhouses were inspected and 9 written orders issued relative to the need of further or different sanitary or ventilating provisions, all of which were complied with. Suggestions as to the improvement of schoolhouse conditions were made in 7 instances, and were acted upon satisfactorily.

Inspection of Slaughterhouses.

Seven slaughterhouses were inspected. They were all found to be clean, and, with 1 exception, the refuse was promptly removed.

Health District No. 7.

J. William Voss, M.D., *Beverly, State Inspector of Health.*

This district includes the cities of Beverly, Gloucester, Lynn and Salem, and the towns of Danvers, Essex, Hamilton, Ipswich, Lynnfield, Manchester, Marblehead, Middleton, Nahant, Peabody, Rockport, Saugus, Swampscott, Topsfield and Wenham.

Local Nuisances.

The attention of the Peabody board of health was called to the fact that the sewage of a number of leather factories in Peabody was still permitted to empty into the North River, thus violating the law. Twenty-one factories have since connected with the sewer and others are making arrangements to do so.

Attention was also called to the Peabody board of health of the unsanitary conditions of many yards, due to the lack of a proper method of collecting swill and ashes.

A large number of buildings, consisting of tenement houses, boarding houses, private dwellings and mercantile establishments, have not yet connected with the sewer, which was completed two years ago, notwithstanding the fact that the State Inspector of Health urged the local health authority to require such connection. The sewage from these buildings is still emptied directly into the street drain.

A nuisance was investigated in the city of Gloucester, as follows: the main drain pipe of the city, which carries the sewage of the city's public buildings, schoolhouses, as well as that of private residences, empties on the most frequented beach of the city, near the bath-houses patronized by children.

Two systems of sewer pipes in Gloucester empty at Vincent's Cove. This is a filthy cesspool, in spite of the rise and fall of the tide, and should be abolished. Another system of sewer pipes empties into a stagnant ditch on the flats near the Annisquam River. There are also a number of sewer outlets near the wharves, which create a stench and pollute the water.

Other nuisances found in Gloucester were a number of overflowing cesspools and open sink drains which run into the public streets. In some parts of the city collections of filth and of decayed animal and vegetable matter were found.

All the conditions above mentioned were brought to the attention of the local board of health, although no action was taken to remedy the same.

A nuisance was investigated in Marblehead consisting of a brook which was used for the disposal of sewage. The brook was in a very filthy condition.

Factory Hygiene.

During the year 314 factories were visited, in 42 of which conditions were found satisfactory, so that no changes were requested.

Four hundred violations of the law were discovered, and the employers notified, as follows: —

Improper water-closet provisions,	168
Sputum receptacles not provided,	124
Inadequate removal of dust for the protection of employees,	58
First-aid outfit not provided,	31
Lack of cleanliness,	16
Inadequate ventilation,	2
Poor light,	1

In the 62 factories reinspected 50 of the violations previously noted were complied with, some of the changes having been made at considerable expense. Whenever an improvement was found to be unsatisfactory, further changes were requested.

Lighting. — The light in shoe factories was interfered with in many instances by dust from the buffing machines, which in its discharge through pipes out of doors settled to a considerable extent on the window glass.

Ventilation. — The ventilation of tanneries was found to be very good, because of the fact that a constant current of air for the drying of the hides was necessary. This was accomplished by huge blowers, which provided a constant supply of fresh air and carried off all fumes and disagreeable odors.

Removal of Dust. — The removal of dust caused by certain processes in shoe factories was, on the whole, fairly satisfactorily accomplished.

Receptacles for Sputum. — Spitting on the floor was observed in many of the factories visited, but the failure of some local health authorities to make specific requirements, in accordance with section 2 of chapter 503 of the Acts of 1907, prevented the enforcement of said statute.

In every factory visited the superintendent and the foremen were informed as to the danger of spitting on the floor, and it was found on visiting a factory the second time that there was considerable less spitting by the employees.

Drinking Water. — Most of the factories visited used the town water supply for drinking purposes. In a few factories the water used was from artesian wells, but no reason appeared for suspecting the purity of these supplies.

Water-closets. — The water-closets in a number of the factories were found in a neglected condition, — poorly ventilated, poorly lighted and unclean. In Peabody 27 factories were still using unsanitary privies, although the town sewer was easily accessible. Twenty-one of these factories have since connected with the sewer, and others are making arrangements to do so.

Health of Minors in Factories.

During the year 4,673 minors were seen. A personal and family history was obtained so far as possible, and in 89 instances a physical examination was made. Of 22 minors with a tubercular family history but 1 was found who showed definite signs of tuberculosis, and in this case a letter was written to the minor's father calling his attention to the disease. Four minors with non-tubercular family histories were found to have definite signs of tuberculosis. One was under the care of a physician, while the condition of the other 3 was brought to the attention of their parents. Five minors, although not showing definite signs of tuberculosis, were in such poor physical condition as to suggest this disease, consequently their parents were notified. Other conditions of ill health found among minors were as follows: 15 cases of bronchitis, 4 of anæmia, 2 of asthma, and 1 each of laryngitis, epilepsy, disease of bladder, disease of eye, septic ulcer of leg, pseudo angina pectoris, growth in nose, neuritis, headache (cause undetermined). Two of the cases, the ulcer of the leg and the growth in the nose, were referred to a hospital.

Tenement Hygiene.

Five hundred and five visits were made to the homes of persons working on clothing in tenements and dwellings; 460 licenses were issued. In every instance the work was done under good sanitary conditions. The work in this district consists chiefly of crocheting on ladies' undervests.

Hygiene of Schoolhouses and Public Buildings.

An examination was made of the sanitary and ventilating provisions of 37 schoolhouses and 6 other public buildings. The sanitary conditions of 5 schoolhouses were unsatisfactory, and the school authorities were so notified.

Health District No. 8.

William Hall Coon, M.D., *Haverhill, State Inspector of Health.*

This district includes the cities of Haverhill, Lawrence and Newburyport, and the towns of Amesbury, Andover, Boxford, Georgetown, Groveland, Merrimac, Methuen, Newbury, North Andover, Rowley, Salisbury and West Newbury.

The work of the year consisted in the inspection of factories, the examination of minors in factories, the investigation of local nuisances, and the investigation of outbreaks of diseases dangerous to the public health.

Diseases Dangerous to the Public Health.

During the year the following outbreaks of communicable diseases were investigated and reported upon: measles in Haverhill; diphtheria and typhoid fever in Lawrence; typhoid fever in Newburyport.

The manner in which local boards of health dealt with communicable diseases was found to be unsatisfactory in some instances. The Haverhill and Amesbury boards of health did not disinfect houses vacated by tuberculosis patients upon the removal or death of the patients.

The board of health of Lawrence formerly released cases of diphtheria from quarantine on the report of the attending physician that the patient had recovered. Under a recommendation of the State Inspector of Health the following regulation was passed: —

> In a case of diphtheria the house in which the disease exists shall remain placarded and all rules relative to diphtheria shall remain in force for at least ten days after the attending physician has reported that a sick person has recovered, unless a negative culture from the throat of the patient had been obtained before that time.

In the investigation of diphtheria and typhoid fever outbreaks in Lawrence it was observed that milkmen had the habit of leaving their milk bottles in houses where persons were ill with communicable diseases. This matter was brought to the attention of the Lawrence board of health, which board passed a regulation prohibiting this practice. This board of health also voted that quarantine laws be strictly enforced, and that the agent of the board be empowered to print placards in such languages as he might find necessary.

On several occasions the State Inspector of Health was called upon by the local boards of health to examine cases with suspicious eruptions. In one instance a diagnosis of smallpox was established.

Local Nuisances.

The attention of the Lawrence board of health was called to the following nuisances: —

Collections of filth in alleyways in the tenement district. Conditions were improved.

Conditions of overcrowding existing in the tenement district occupied by Greeks, Armenians and Syrians. The board of health investigated the conditions, and posted notices in all the rooms in these houses, restricting the number of persons allowed to sleep in any one room.

A nuisance created by the emptying of the Shanty Pond sewer into the Merrimack River. When the water is low the outlet of this sewer is uncovered, and the effluvia from the sewage is noticeable. The board of health referred the matter to the city council, with the request to carry the sewer to a point below the low-water mark. The matter is still pending.

A nuisance consisting of a stench from the river bed of the Spicket River. The authorities of the Arlington Mills, where the river dam is located, were persuaded to flush the river bed every morning. Conditions are somewhat improved.

The following matters were brought to the attention of the Haverhill board of health: —

Collections of filth in the alleyways in the shoe district. This matter was referred to the city solicitor, who stated that inasmuch as dirt is not *prima facie* evidence of disease, the board was not called upon to take any action.

A nuisance consisting of the unsanitary condition of Little River. This matter was referred to the city solicitor, who stated that he thought it ought to be referred to the Legislature.

A nuisance consisting of dumping street sweepings in a vacant lot behind a factory. The nuisance was abated. The lot is no longer used as a dumping ground.

The attention of the inspector of buildings of Haverhill was called to a nuisance consisting of the discharge of dust, from the buffing machines in shoe factories, into the street in such a way as to cover the windows of neighboring factories, so as to interfere with the proper lighting of the workrooms. The inspector has since begun enforcing the city ordinance prohibiting the discharge of dust into the open street, and conditions have improved.

The following matters were brought to the attention of the board of health of Newburyport: —

A nuisance consisting of uncleanly water-closets situated in an outbuilding. The closets were cleaned out, and the premises are to be connected with the public sewer.

A nuisance consisting of an unsanitary condition of a piggery on the Adams farm was abated.

The attention of the board of health of North Andover was called to the following matters: —

A nuisance consisting of a broken sewer drain was abated by laying a new drain.

A nuisance consisting of dirty premises. The nuisance was abated.

The attention of the Amesbury board of health was called to a nuisance which had existed for years, consisting of the emptying of the sewage of 15 houses in a vacant lot at the foot of the street on which these houses were

located. Following the suggestion of the State Inspector of Health a cesspool was placed at the outlet of the sewer common to these houses, and conditions were greatly improved.

The attention of the board of health of Methuen was called to the following: —

A nuisance caused by the unsanitary condition of a slaughtering establishment. The license of the establishment was revoked until changes were made satisfactory to the board of health.

A nuisance caused by the dumping of swill and offal in a vacant lot. The nuisance was abated.

The attention of the Salisbury board of health was called to the following: —

A nuisance consisting of the emptying of the sewage from a house into a brook required the provision of a cesspool. The owner of the house was instructed to build a cesspool, and upon his refusal to do so the case was prosecuted by the local board of health, and orders were issued by the court that a cesspool be constructed. A satisfactory cesspool was constructed.

Factory Hygiene.

One hundred and forty factories and workshops were inspected, and 167 subsequent visits made. Following the first inspections letters were sent to 53 manufacturers and suggestions made to 36, relative to objectionable conditions found. Sixty-eight of the 107 orders or suggestions made were complied with; of these, 10 related to ventilation, 5 to cleanliness, 6 to providing seats for women, 1 to providing pure drinking water, 1 to providing for first-aid outfits and 45 to providing proper water-closets.

Ventilation. — In the crowded stitching rooms in the shoe factories visited in Haverhill and Newburyport the employees frequently complained of headache when the gas was burning. The ventilation of the water-closets of these factories, by means of galvanized iron flues, was found inadequate. In 1 establishment, at the suggestion of the State Inspector of Health, all the water-closets were connected with a common blower system, which gave satisfactory results. Two other establishments now use similar methods for the ventilation of water-closets.

The dyehouses of establishments were found inadequately provided with devices for the removal of steam from the room. In 1 mill the dyehouse at time of visit was so full of steam that it was impossible to discern objects at a distance of more than two feet. This condition was improved, at the suggestion of the State Inspector of Health, by equipping the kettles with hoods.

Lighting. — The larger shoe factories in Haverhill are in the main well lighted. In the smaller factories, situated in districts where the buildings are crowded together, sufficient daylight in all the rooms is impossible. On certain days, depending upon the degree of moisture in the atmosphere, the dust discharged out doors from the flues of the dust-producing machines so covers the windows of some buildings as to interfere seriously with the admission

of light. This occurs in spite of the building regulations, which require that all flues must so terminate that the dust from them cannot blow against any other building, or any street or way. The operatives in the stitching rooms of the shoe factories frequently suffer from derangements of vision, and have to wear glasses if they are to continue at their work.

Removal of Dust. — In 1 mill 6 of the 12 carding machines in operation were equipped with blowers, which were not effectively removing the dust. Dust created in the process of picking and shaking flax was not well taken care of by the blower system in use. At the request of the State Inspector of Health efforts were made to cause an adequate removal of the dust. The majority of the employees in this room looked anæmic and appeared to have low vitality. In 1 mill a satisfactory arrangement was observed whereby dust from the carding machines was removed through openings in the floors underneath the machines.

Several processes giving rise to a great deal of dust were observed in an establishment where felt hats are manufactured from the fur of Australian rabbits. The mixing of the various qualities of fur in the desired proportions, and the carding and combing of the fur, gave rise to a great deal of dust, which from the nature of the processes could not be removed by air currents. The process of "pouncing," that is, sandpapering the hat to give it a finish, gave rise to considerable dust, which was, however, fairly well taken care of by hoods and suction pipes.

Drinking Water. — Pure drinking water was found provided for the employees in all the manufacturing establishments visited. In several factories where water from the Merrimack River was used in some of the sinks placards were placed over the taps reading: "Canal water; not to be used for drinking purposes."

Receptacles for Sputum. — Letters were sent to all the boards of health in the district calling their attention to section 2, chapter 503 of the Acts of 1907. Many of the manufacturing establishments have not as yet provided receptacles for sputum, owing to the failure of the local boards of health to issue their regulations in the matter.

Foundries. — Of 2 foundries visited, 1 was in process of construction, and was provided with satisfactory toilet and washing facilities. In the other the toilet arrangements were not satisfactory, due to the fact that there was no public sewerage system in the town.

Court Case. — On February 5 proceedings were instituted against Lewis Martin of Haverhill for not providing separate water-closets for the male and female employees of his establishment. The case came before Judge Fuller in the district court of Haverhill, on Feb. 13, 1908. The defendant was found guilty and the case placed on file.

Health of Minors in Factories.

The health of minors employed in factories in the district was, in the main, found to be good. The conditions under which they were found at work in the factories were, in many instances, much more sanitary than those in the

tenements where they lived. During the year 5,169 minors were observed, and of this number 131 were examined because of (*a*) tubercular family history, (*b*) previous personal history and (*c*) the appearance of the minor. Forty-one of the minors examined were found in ill health, 31 of whom were females. Six minors who gave a tubercular family history were found to be in good physical condition, showing no evidence of the disease. One minor giving such history was found in poor physical condition, although no definite signs of the disease were found. Two minors were found suffering from tuberculosis, both of whom were working in clean, well-ventilated rooms. One minor, suffering from chronic bronchitis, possibly tuberculosis, was referred to the tuberculosis clinic for observation and for the examination of his sputum.

Among some of the other conditions of ill health found were 6 cases of anæmia and ill nutrition, 2 cases of adenoids, 1 case each of chlorosis, asthma, epilepsy, petit-mal and macroglossia, and 2 cases of ptosis of the right eyelid, 1 with external strabismus of the left eye and 1 of myopia.

Tenement Hygiene.

Thirty-four licenses were issued for the manufacture of wearing apparel in tenement workrooms. The applicants for these licenses were found to live in very comfortable and clean homes. In one tenement workroom a case of measles occurred, and, at the suggestion of the State Inspector of Health, the goods found on the premises were disinfected by the local board of health before they were returned to the factory.

Hygiene of Public Buildings and Schoolhouses.

Three schoolhouses and a number of public buildings were visited. In 2 public buildings the water-closets were not found in proper condition. The local board of health issued orders for changes in the Academy of Music in Haverhill and the requested changes are now being made. Written orders to improve conditions in the water-closets of the Boston & Northern waiting room, Lawrence, were issued by the State Inspector of Health, and satisfactory changes were made.

The attention of the superintendent of schools of Lawrence was called to the unsanitary conditions of the urinals in the Newbury Street School. This matter was referred to the superintendent of public property.

On June 30, 1908, the attention of the State Inspector of Health was called to the sanitary conditions of the Currier Grammar School building, Newburyport. An inspection of the premises showed that proper water-closets were not provided, owing to the fact that the building was not connected with the sewer. The attention of the board of health of Newburyport was called to the matter, and it was suggested that they request the city government to connect the Currier Grammar School with the public sewer. This request was made by the board of health on Sept. 3, 1908. The ventilation of some of the rooms in the school was found inadequate, and in order to meet the statute requirements ventilators were installed.

Inspection of Slaughterhouses.

Six slaughterhouses were inspected, 5 of which were found in an unsanitary condition.

HEALTH DISTRICT No. 9.

CHARLES E. SIMPSON, M.D., *Lowell, State Inspector of Health.*

This district includes the cities of Lowell and Woburn, and the towns of Acton, Arlington, Ayer, Bedford, Billerica, Boxborough, Burlington, Carlisle, Chelmsford, Concord, Dracut, Dunstable, Groton, Harvard, Lexington, Lincoln, Littleton, Maynard, Pepperell, Shirley, Stow, Tewksbury, Townsend, Tyngsborough, Westford, Wilmington and Winchester.

The work of the year in general consisted in the inspection of factories, examination of minors in factories, inspection of schoolhouses, inspection of tenement workrooms, and investigation of communicable diseases that occurred in the district.

Diseases Dangerous to the Public Health.

Five cases of laryngeal diphtheria in North Tewksbury were investigated, and thought to be due to milk infection. Immediate precautions were taken to check further spread of the disease.

Six cases of typhoid fever occurred in one boarding house in Townsend. The source of the infection was probably from an old cistern in the cellar of the house, which was exposed to pollution from a privy.

Several cases of typhoid fever occurred in one family in Lowell which were investigated and reported upon in April.

An investigation of an outbreak of scarlet fever in Winchester disclosed the fact that it was confined to one section of the town, and that for the most part those afflicted were pupils in one school. The cause of the outbreak was attributed to a child ill with the disease in another part of the town, who had broken quarantine established by the loeal board of health. The State Inspector of Health discovered that the local board of health took no action against the persons who were responsible for releasing the child from quarantine, inasmuch as previous to the present outbreak court proceedings were instituted against several persons for a similar offence, and the cases were brought before the court in such a way that the judge did not see fit to support the board. One of these cases was decided against the board of health on the ground that quarantine from scarlet fever was an unreasonable by-law for a local health authority to make, and the other cases brought into court are still pending.

A great deal of time was spent investigating the unusually large number of typhoid cases that occurred in Lowell. One possible explanation of the increased number of cases is that, owing to the dry season, the farmers were obliged to use water from sources not generally used, and there is a possibility that some of these sources were polluted. An investigation of the premises of one milkman on whose place there was a number of cases revealed

the fact that the bookkeeper of this milkman had been stricken with typhoid fever, and that one man who was handling the milk showed a positive Widal test, without any previous history to account for it.

A diphtheria outbreak was investigated in company with the Lowell board of health in December, 1907, and it was found that a number of cases occurred in one charitable institution, and that these were in all probability infected by the cook of the institution, who visited her child in an infected house. Many of the cases in the city were so mild that no physician was summoned, and the patients were not properly quarantined.

Factory Hygiene.

During the year 225 factories, employing 42,600 operatives, were visited, covering 34 different industries. In 86 factories attention was called to 115 violations of the law, and orders were given requesting compliance with the law. Reinspections made in 66 of these factories disclosed the fact that 74 violations of the law were remedied. In 1 factory there seemed to be good reason why compliance with the orders was delayed.

It is an interesting fact that one of the cleanest and best-appointed mills in the district was an old one, in which even the plumbing was not modern.

Light and Ventilation. — The general sanitary condition of the factories was found to vary greatly, even in the same industry. As a rule, light and ventilation were not so good in old buildings as in recently constructed buildings. The light in many of the factories might be greatly improved if more attention were given to whitewashing the walls and ceilings. One superintendent stated that the expense of lighting in the factory was considerably reduced by keeping the walls and ceilings in a whitened condition. A large number of mills visited were using electric lights, and a number of the older mills were changing from gas light to electric light, thus improving the light and diminishing the products of gas combustion. The dry-finishing rooms of the paper mills were found to be hot and poorly ventilated, conditions entirely unnecessary, inasmuch as removing the heat from the room removes also the moist air, and hastens the drying process. One agent had the heat particularly well taken away from an expensive finishing machine, which had so heated the room as to make it very uncomfortable for the employees, by increasing the rapidity of the fan, and, to his surprise, found that he had increased the capacity of the machine about 40 per cent.

Drinking Water. — The drinking water supply was found satisfactory in all factories visited. As a rule, town water was used, rarely water from a tested well. In several factories where canal or other impure water was drawn in the sinks, it was found that no signs warning employees against the use of the water for drinking purposes were posted, although, in every case, pure drinking water was provided at convenient places in the room. One firm, employing a very large number of operatives, was induced to change its water pails, which were frequently exposed to the dust of the room, to tin-lined, well-covered and jacketed tanks.

First-aid Outfits. — First-aid outfits were pretty generally installed, and in many cases were found useful. In the larger factories, however, it was noted that if only one outfit was provided some time must elapse, in cases of emergency, before it could be brought into use.

Water-closets. — While in general the water-closets were found fairly satisfactory, many firms were gradually replacing the cast-iron bowls by modern types. Only in 4 factories was it necessary to issue orders relative to changes. All these orders were complied with. Separate closets for the sexes were found provided in every factory, although in some instances they were not properly designated. In one old mill new water-closets, with modern sanitary appliances, were installed throughout the plant.

Humidifying in Factories. — In some of the mills the water sprayed into the workrooms by drosophores was taken directly from the canal, containing all the contaminations of the Merrimack River, which includes to some extent human excrement.

Receptacles for Sputum. — A great deal of the delay in installing sputum receptacles in factories is caused by the fact that the local boards of health, except one, have not yet issued the requirements in regard to the construction and number of receptacles, in accordance with section 2, chapter 503 of the Acts of 1907. The managers of all the factories visited were spoken to. The meaning and significance of the law requiring receptacles for sputum was explained to them, and their co-operation was obtained in the efforts to stop spitting on the floors. It was also found that a more extensive educational work among the operatives would make the antispitting laws more effective. Fifty firms installed the receptacles.

Seats for Women. — In every factory visited, except 1, seats were provided for women employees. In this factory the omission was due to carelessness of the overseer rather than to intentional neglect on the part of the management. When the attention of the manager was called to the law he promised to provide seats immediately.

Industrial Hygiene. — The Relation of Industries, Processes or Unhygienic Conditions to Health.

Cotton Mills. — Various devices were observed in use to remove cotton dust from carding rooms. An attempt was made in some places to have men who operate carding machines wear respirators, but the men preferred the ineffectual method of putting a bunch of raw cotton between their teeth. Such a practice does not protect the nose. The napping rooms were also found dusty, but a number of mills have put in extensive blower systems to take care of the dust.

Waste Establishments. — The operatives in these establishments would seem to be exposed to danger since they have to handle so many kinds of rubbish swept up from the factory floors. No indication of any sickness, however, was found among them.

Machine Shops and Foundries. — In general, disregard of the law relative to hoods and hoppers for emery and buffing wheels was found in the small machine shops and foundries. In 1 establishment the hoppers had all been removed from the pneumatic tubes around emery wheels in the grinding room, apparently by the employees, although such protective devices appeared necessary for the health of the grinders.

The Manufacture of Storage Batteries. — In the manufacture of storage batteries a dangerous process was observed, consisting of the mixing of the red oxide of lead with litharge. This process was conducted by one man in one corner of a room where several other men were employed. One of the men showed signs of lead poisoning. In accordance with the suggestions of the State Inspector of Health the corner was partitioned off, and the mixing is now carried on in closed receptacles, and the man in charge of the process wears a respirator. It was also suggested that while applying the moist mixture on the plates the man should wear rubber gloves, or should, after the operation, use extreme care in washing his hands. Another process of interest in the manufacture of storage batteries, from the point of view of the health of the employees, consisted in the hardening of the plates by dipping them in sulphuric acid. This process liberates a gas which occasionally overcomes the workmen, who may remain for an hour or longer in an unconscious condition. This room is well ventilated by a number of apertures, and by a large fan which serves as an exhaust.

Chrome Works. — In the 1 factory of this kind in the district potassium and sodium bichromate are manufactured. The dust of the manufacturing processes attacks the septum of the nose, causing ulceration and perforation. Of 38 men examined in the factory 33 were found to have perforation of the septum and 3 well-marked ulcerations. Of the 3 who had ulcerated septa, 1 had worked three years in the factory, 1 a year and a half, and 1 but three months. Of the 2 who had neither ulceration nor perforation of the septum, 1 was the superintendent, who always took the precaution of plugging his nose with cotton, and the other worked in a department where another kind of work was carried on. Several of the men had indolent ulcers on their hands. All the men seemed to be in good health, and stated that while they were considerably inconvenienced from their nasal discharge and sneezing while the process was active, they felt perfectly well after the perforation was completed. The dust seemed to have no effect on the mucous membrane of the mouth.

Tanneries. — The odors in tanneries, arising especially in the process of rotting hides, seemed offensive and disagreeable. All the men employed there, however, appeared to be in good health. The processes of oiling and finishing the hides were conducted in rather low-studded rooms, and the ventilation in these rooms was not satisfactory. The process of "tacking" as observed in these establishments is one which might be a factor in the spread of infectious disease. While tacking the hides on the frames, for purposes of drying, the workman holds the tacks in his mouth. During

the process many of the tacks fall on the floor and are later swept up and used by other workmen, often without being washed.

Manufacture of Patent Leather. — The workmen in this industry are exposed to the strong fumes of benzine, which is used in the paint. The fact that the rooms are high studded is of no special advantage, as the benzine fumes are heavier than air. Occasionally workmen show symptoms of irritation of the kidneys, and have to leave off work for a month or two. Only young, vigorous men are employed, and they work short hours.

Tuberculosis in Factories.

An effort was made to enlist the assistance of superintendents and overseers in preventing the spread of tuberculosis in factories. A letter was addressed to them in which they were informed that consumption was curable, and that it was their duty to do all they could to help educate those with whom they worked and came in contact. The letter, written by the State Inspector of Health, was in part as follows: —

We ask you, overseers and those in control of factory and shop workers, to take particular notice of the physical condition of your people, and if you notice any who are growing pale, losing flesh or have a cough which is hanging on longer than is usual with a cold, or in any way seem below their normal condition, privately to look into their case. It must be done very quietly, as such people shun publicity, and with the present state of education you may be doing them much harm by calling undue notice to them. Human sympathy is very freely given if sought in the right way, and as quickly withheld if gone at by the wrong method. You should talk to them privately. First, ask a little about their condition; then, if you find reason for it, and if they have not been to their family physician, advise them to, and find out who he is, that we may follow up the case. If there is any good reason why they should not go to him, financially or otherwise, you may give them one of my cards. I will give you on it the address of some doctor who will look the case over carefully and report to me. I will then confer with you as to what course is best.

Yours very truly,
(Signed) CHARLES E. SIMPSON.

As a result of this letter several cases of tuberculosis in adults were brought to the attention of the State Inspector of Health. One employee was found working in a cotton mill at an old-fashioned loom, where the operator put his lips to the shuttle to suck the thread through. The danger of these looms becoming contaminated, and later being used in a similar way by other workmen, is apparent. The man was so situated that he could not give up his work; and the agent of the mill transferred him to a modern loom, and provided him with a drinking cup for his own use, and with a spittoon. Another operative, in the early stages of tuberculosis, obtained admission to Rutland, and as she had no funds $65 was raised by subscription from the office and fellow workers, with the promise of further support if necessary.

In 2 mills which are kept in very good sanitary condition many employees

were found to be small and undeveloped, or in some way below the average as to physical condition. In each instance the industry carried on was of such kind as to invite the less robust or the weaklings.

Health of Minors in Factories.

The general health of minors in factories was good. Of the 6,809 minors seen and questioned, 173 were examined physically because of a tubercular family history in 120 cases, previous personal history in 38 cases and the appearance of the minor in 15 cases. Although in a number of cases requests were made for specimens of sputum, only one specimen was submitted.

The following diseased conditions were found: 8 diseases or disturbances of the eye, including 2 cases of conjunctivitis, 2 of blepharitis and 1 each of squint (O. D.), leucoma (O. C.), pterygium and cataract; 1 case of middle ear disease; 2 cases of nasal affection; 4 cases of tubercular glands; 2 cases of rheumatism; 2 cases of wry neck and curvature of the spine; and 1 case each of tubercular dermatitis, heart disease, tumor of the face and uterine disease; and 9 cases which may be grouped under anæmia, functional circulatory disturbance or debility.

Most of the minors with eye disturbances were found in knitting and stitching rooms. There was but 1 diseased minor found working in a department in which processes dangerous to health were conducted, and none of the other minors found in ill health were exposed to probable unhygienic influences.

Tenement Hygiene.

Most of the work in this district is carried on in clean houses, under good conditions. To protect the public against the spread of communicable diseases from the tenement workrooms it was arranged that any goods found exposed to infection should remain on the premises until fumigated by the local board of health. After such fumigation the goods were removed, in a bag provided for the purpose, to the mill, where they were submitted to further fumigation. Three hundred and thirty-two licenses were issued during the year. Seven licenses were revoked because of the presence of communicable diseases in the workrooms. In 1 instance the local board of health was notified of a person ill with scarlet fever who had broken quarantine.

Schoolhouse Hygiene.

In January, 1908, orders were issued for improved ventilation of the grammar school building in Carlisle, and of a room in the old hotel building used for school purposes, and the town erected a new building, which was opened for the fall term.

The attention of the authorities of Westford was called to the poorly ventilated and overcrowded condition of a schoolhouse situated in Forge Village. Plans were immediately drawn up to double the capacity of the schoolhouse. and work on the building was begun.

Orders were issued to the authorities at Littleton to improve the ventilation of the Center School and of a schoolroom in the town hall. Plans were drawn up and changes made.

An inspection of the Lincoln School in Lowell showed the water-closets to be in an unsanitary condition. Suggestions were made to the authorities that the closets be replaced by closets which should be connected with the sewer.

Miscellaneous.

In November, 1907, the physician representing the town of Dunstable asked advice as to the best way to deal with an epidemic of catarrhal conjunctivitis, which was then prevalent in the schools. Methods of quarantine and other measures were outlined to him and the outbreak was soon under control.

At the request of the Bedford board of health a suspicious case of eruptive disease was examined on April 4, and was diagnosed as chicken pox.

A nuisance consisting of an unclean piggery was investigated in company with the board of health of Dracut. Changes were suggested which have since been carried out.

Of the 3 slaughterhouses visited, but 1 was found in a distinctly unsanitary condition.

HEALTH DISTRICT No. 10.

WILLIAM W. WALCOTT, M.D., *Natick, State Inspector of Health.*

This district includes the cities of Marlborough, Newton and Waltham, and the towns of Ashland, Belmont, Brookline, Dover, Framingham, Grafton, Holliston, Hopedale, Hopkinton, Hudson, Medfield, Medway, Mendon, Milford, Millis, Natick, Needham, Northborough, Sherborn, Shrewsbury, Southborough, Sudbury, Upton, Watertown, Wayland, Wellesley, Westborough and Weston.

The work consisted mainly of the inspection of factories, the examination of minors in factories, and the investigation of diseases dangerous to the public health.

Diseases Dangerous to the Public Health.

Several cases of typhoid fever were investigated on the premises of several milk producers in the district, and with the exception of 1 case all the necessary precautions were taken so that no new cases resulted from them. In 1 instance, however, the wife of a milk producer was taken sick with typhoid fever, and, notwithstanding a positive Widal test, the husband refused to accept the diagnosis, dismissed the attending physician, took no precautions, and continued collecting and distributing milk. The attention of the local board of health was called to the matter, and they were advised to compel the milk producer to discontinue his milk business for a while, and to take all necessary precautions. In spite of orders issued by the health authorities the man continued to collect and distribute milk. The case was therefore brought to court. The milkman was found guilty under section 49, chapter 75 of the Revised Laws, and the case was placed on file.

An outbreak of 6 cases of scarlet fever, on the boundary line between Needham and Dover, was investigated, and was traced to an unrecognized scarlet fever case that had been diagnosed as influenza.

An outbreak of 25 cases of scarlet fever among the French families of Fisherville was investigated. No possible source of infection could be traced to the milk supply common to all these families. Further investigation showed that all the patients were in the families of the pallbearers at a public funeral of a baby who had died a few hours after having been seen once by a physician. All the cases appeared from two to ten days after the day of the funeral, and in all probability the child whose funeral they attended died from scarlet fever. The manager of the Fisherville Mills did all he could to prevent the spread of the disease by excluding all doubtful cases from the mills, and providing at his own expense a fumigating outfit.

Between July 25 and August 25 a number of cases of dysentery occurred in Natick. The total number of cases was estimated to be about 160, with a mortality of 12. These estimates are probably high, as some of the cases of ordinary diarrhœa were doubtless included in the number. There were some difficulties in connection with this investigation, as neither the physicians nor the hospital kept detailed records of the cases. The stools of three hospital cases were sent to the Massachusetts General Hospital, and a paratyphoid bacillus was isolated. All the physicians were notified of the findings, and advice was given that such precautions be taken with the stools as is customary with typhoid stools.

Factory Hygiene.

Of the 231 factories visited during 1907, 2 were burned, 1 was moved out of the State, and several were closed on account of business depression. In 1908 205 were inspected, and 201 reinspected. Twenty orders were issued, providing for (*a*) adequate protection of the employees against dust, (*b*) sputum receptacles, (*e*) first-aid outfit, and (*d*) a greater degree of cleanliness; and, except in one instance, all were complied with. In accordance with suggestions made by the State Inspector of Health, 5 manufacturers changed the location of their water-closets, so that they ceased to empty directly or indirectly into the Charles or Assabet rivers.

Lighting. — The factories in the district were found, as a rule, very well lighted. The walls and ceilings of many were found white, and in a large number prismatic glass was used to improve the light. One factory spent $2,200 during the year to put prismatic glass in the windows. This change increased the efficiency of the operatives, as well as decreased, to a large extent, the expense of lighting. In the shoe factories the benches of the operatives were in front of the windows, while the central and darker parts of the room were used for shoe racks. One of the best-lighted factories in the district was a watch factory, where the nature of the industry required perfect lighting. The rooms were long, rather narrow, with a row of large windows on either side supplied with many lights of prismatic glass, which threw a clear, white light into the center of the room. The walls and ceilings were light. There

were separate curtains for the upper and lower sash of each window, in order that the light might be admitted from above or below, as needed, as well as many movable screens which were in constant use. The buildings were surrounded by parks and had the river on one side, so that there were no outside obstructions. They were so constructed that the different wings did not obstruct light. In 1 factory a comparatively dark basement was well lighted by the use of prismatic glass.

Ventilation and Removal of Dust. — An effort was made by the State Inspector of Health to collect facts in regard to ventilation and the removal of dust in factories, with special attention to the type of blowers used, the size and shape of hoods and suction pipes, as well as the approximate cost of construction and operation. He was thus able to give intelligent advice as to the methods of improving ventilation and the removal of dust. In 1 shoe factory, for example, where the blowers for the removal of dust were not efficient, it was suggested that the size of the pipes be increased from 10 to 16 inches, thus diminishing the friction. These changes were made, with very satisfactory results. Many excellent ideas were noted in regard to hoods. In 1 watch factory, for instance, several dry grinders that travel were in operation. The hoods and branch exhaust pipes were so arranged that they traveled also, and kept the grinders covered all the time. In 1 factory the operatives were protected from steel and emery dust by having glass windows in front of the hoods, so that it was possible to watch the work with safety.

Humidifying in Factories. — In some of the cotton mills visited the artificial moisture introduced was not properly regulated, and was frequently found too high. It was often regulated by the foreman according to the "feel or taste" of the air. In several mills, however, tables by which the degrees of humidity might be accurately regulated were found to be in use.

Seats for Operatives and Arrangement of Machines. — In the cotton industry it was observed that the operatives could save a good deal of energy, and do more effective work, if the machinery were properly arranged. The weavers, for instance, spend most of their energy in walking from loom to loom. It can be easily calculated that the amount of walking a weaver has to do when the machinery is arranged in a double-alley system is considerably less than when arranged in a single-alley system; and, moreover, he can attend to a larger number of looms. In some cases the walking of the weaver from loom to loom was practically eliminated by a movable seat running on rails, which could be readily started and stopped.

What Some Manufacturers are doing to increase the Comfort of the Operatives.

One manufacturer provided a very comfortable boarding house for girls employed in his factory, at a cost of $3.50 per week. The food served was substantial and well cooked. The rooms were comfortable, light and clean. He also built a kindergarten on the factory grounds, provided a teacher, and maintained the school at his own expense. This school was not only for the

children of the operatives, but for any child in the neighborhood who cared to attend. Tennis and hand ball courts on the grounds could be used by the employees at a cost of 25 cents per year. This included the use of nets, balls and racquets.

Another concern provided a large athletic field, boathouses and bath houses. They have an annual field day when the factory is closed. The concern owned a number of cottages, which were arranged with one "rear street" between each two rows of buildings. The operatives rented these at very reasonable rates. The garbage cans shown in the picture are put out every morning, and emptied at the company's expense into covered wagons. Each tenant kept the grounds about his house in good condition. The company provides each year $400 for cash prizes for the best kept grounds. The grounds are inspected and marked four times during the season, thus giving every one a fair chance. A member of the management said that between the athletic grounds and the gardens the operatives spent much of their spare time out of doors. The older men worked in their yards and gardens, while the youngsters spent much time on the athletic field, training for the annual field day.

In 2 factories lunch rooms were provided in the buildings and hot lunches served at cost. In both places the managers stated that as a result of serving lunches they noticed increased efficiency, especially among the girl operatives. Before the lunch rooms were installed the girls often went home at noon on a rainy day and did not return, or, if they did return, they often lost a day or two on account of colds, as many lived from one to two miles away from the factory.

One factory had a large lunch room on the top floor of the building, and it was also provided with a piano. Lunches were served at cost.

In 1 foundry there were very elaborate wash rooms. Every man had his own private bath room, with hot and cold water, a locker for his clothes, and a warm place to undress and dress. The floor was of cement, as seen in one of the accompanying illustrations, and so constructed as to drain toward the center.

Health of Minors in Factories.

Most of the minors were found to be employed in 56 of the 205 factories visited. One factory employed more than 500 minors. On the other hand. 63 factories employed none.

Of the 2,996 minors seen, 48 were examined physically because of tubercular family history, previous personal history or the appearance of the minor: of which number but 4 (1 male and 3 females) were found in ill health, each of whom was under eighteen years of age. The conditions of ill health were tuberculosis, goiter and heart disease. Forty-four minors appeared anæmic, but the physical examination in each case was negative. Only in 1 instance were the parents of the minor notified.

None of the minors appeared to be exposed to probable unhygienic influences. The factories employing the largest number of minors are, as a rule, located in the country, and the minors live in comfortable cottages.

COVERED GARBAGE CANS.

Machine Shops and Foundries. — In general, disregard of the law relative to hoods and hoppers for emery and buffing wheels was found in the small machine shops and foundries. In 1 establishment the hoppers had all been removed from the pneumatic tubes around emery wheels in the grinding room, apparently by the employees, although such protective devices appeared necessary for the health of the grinders.

The Manufacture of Storage Batteries. — In the manufacture of storage batteries a dangerous process was observed, consisting of the mixing of the red oxide of lead with litharge. This process was conducted by one man in one corner of a room where several other men were employed. One of the men showed signs of lead poisoning. In accordance with the suggestions of the State Inspector of Health the corner was partitioned off, and the mixing is now carried on in closed receptacles, and the man in charge of the process wears a respirator. It was also suggested that while applying the moist mixture on the plates the man should wear rubber gloves, or should, after the operation, use extreme care in washing his hands. Another process of interest in the manufacture of storage batteries, from the point of view of the health of the employees, consisted in the hardening of the plates by dipping them in sulphuric acid. This process liberates a gas which occasionally overcomes the workmen, who may remain for an hour or longer in an unconscious condition. This room is well ventilated by a number of apertures, and by a large fan which serves as an exhaust.

Chrome Works. — In the 1 factory of this kind in the district potassium and sodium bichromate are manufactured. The dust of the manufacturing processes attacks the septum of the nose, causing ulceration and perforation. Of 38 men examined in the factory 33 were found to have perforation of the septum and 3 well-marked ulcerations. Of the 3 who had ulcerated septa, 1 had worked three years in the factory, 1 a year and a half, and 1 but three months. Of the 2 who had neither ulceration nor perforation of the septum, 1 was the superintendent, who always took the precaution of plugging his nose with cotton, and the other worked in a department where another kind of work was carried on. Several of the men had indolent ulcers on their hands. All the men seemed to be in good health, and stated that while they were considerably inconvenienced from their nasal discharge and sneezing while the process was active, they felt perfectly well after the perforation was completed. The dust seemed to have no effect on the mucous membrane of the mouth.

Tanneries. — The odors in tanneries, arising especially in the process of rotting hides, seemed offensive and disagreeable. All the men employed there, however, appeared to be in good health. The processes of oiling and finishing the hides were conducted in rather low-studded rooms, and the ventilation in these rooms was not satisfactory. The process of "tacking" as observed in these establishments is one which might be a factor in the spread of infectious disease. While tacking the hides on the frames, for purposes of drying, the workman holds the tacks in his mouth. During

the process many of the tacks fall on the floor and are later swept up and used by other workmen, often without being washed.

Manufacture of Patent Leather. — The workmen in this industry are exposed to the strong fumes of benzine, which is used in the paint. The fact that the rooms are high studded is of no special advantage, as the benzine fumes are heavier than air. Occasionally workmen show symptoms of irritation of the kidneys, and have to leave off work for a month or two. Only young, vigorous men are employed, and they work short hours.

Tuberculosis in Factories.

An effort was made to enlist the assistance of superintendents and overseers in preventing the spread of tuberculosis in factories. A letter was addressed to them in which they were informed that consumption was curable, and that it was their duty to do all they could to help educate those with whom they worked and came in contact. The letter, written by the State Inspector of Health, was in part as follows: —

We ask you, overseers and those in control of factory and shop workers, to take particular notice of the physical condition of your people, and if you notice any who are growing pale, losing flesh or have a cough which is hanging on longer than is usual with a cold, or in any way seem below their normal condition, privately to look into their case. It must be done very quietly, as such people shun publicity, and with the present state of education you may be doing them much harm by calling undue notice to them. Human sympathy is very freely given if sought in the right way, and as quickly withheld if gone at by the wrong method. You should talk to them privately. First, ask a little about their condition; then, if you find reason for it, and if they have not been to their family physician, advise them to, and find out who he is, that we may follow up the case. If there is any good reason why they should not go to him, financially or otherwise, you may give them one of my cards. I will give you on it the address of some doctor who will look the case over carefully and report to me. I will then confer with you as to what course is best.

Yours very truly,
(Signed) CHARLES E. SIMPSON.

As a result of this letter several cases of tuberculosis in adults were brought to the attention of the State Inspector of Health. One employee was found working in a cotton mill at an old-fashioned loom, where the operator put his lips to the shuttle to suck the thread through. The danger of these looms becoming contaminated, and later being used in a similar way by other workmen, is apparent. The man was so situated that he could not give up his work; and the agent of the mill transferred him to a modern loom, and provided him with a drinking cup for his own use, and with a spittoon. Another operative, in the early stages of tuberculosis, obtained admission to Rutland, and as she had no funds $65 was raised by subscription from the office and fellow workers, with the promise of further support if necessary.

In 2 mills which are kept in very good sanitary condition many employees

Three factories, where from 300 to 600 minors are employed, maintain very good sanitary conditions, and are in some respects models. One factory, where the sanitary conditions last year were found distinctly bad, was closed during the business depression.

In certain parts of the district minors live in crowded tenements, and it was among the employees who live in such homes that the poorly nourished and anæmic appearing minors were discovered.

Schoolhouse Hygiene.

The school committee of Wayland was ordered to change conditions in privies and urinals, and to improve the ventilation in one school. The school committee of Dover was ordered to improve the ventilation in one small room, where coal gas was usually detected. All these conditions were improved.

Tenement Hygiene.

One license was issued for working on clothing in a dwelling house.

Inspection of Slaughterhouses.

An inspection of slaughterhouses where the practice of killing bob veal was alleged revealed a cow which was much emaciated, with tubercular nodules in the posterior upper part of the udder. The local cattle inspector was consulted and the cow was killed. A post-mortem examination showed tuberculosis of the udder. A further inspection of the slaughterhouses revealed no objectionable conditions, although an inspection of one of the markets which bought from the slaughterhouses disclosed about sixty pounds of veal unfit for use. The veal was destroyed.

Health District No. 11.

Melvin G. Overlock, M.D., *Worcester, State Inspector of Health.*

This district includes the city of Worcester, and the towns of Auburn, Brookfield, Charlton, Douglas, Dudley, Leicester, Millbury, Northbridge, North Brookfield, Oxford, Southbridge, Spencer, Sturbridge, Sutton, Uxbridge, Warren, Webster and West Brookfield.

The work for the year consisted chiefly of the inspection of factories and the examination of minors in factories, and the inspection of slaughterhouses, schoolhouses and public buildings.

Diseases Dangerous to the Public Health.

The towns of Spencer and West Brookfield were visited by the State Inspector of Health to determine why no cases of diseases dangerous to the public health were reported during the year 1907 to the State Board of Health, and it was found that there had been 9 cases of scarlet fever and 1 case of typhoid fever in Spencer; and 1 case of diphtheria and 1 of measles in West Brookfield.

Factory Hygiene.

Letters were sent to 95 manufacturers calling attention to 106 violations of the statutes, 60 of which were complied with.

Light and Ventilation. — With 1 exception all the factories visited were found well lighted. In this factory satisfactory changes were made. The employees in some factories refused to utilize provisions for ventilation. In 1 case, for instance, fans were used to blow fresh air into the factory, and the top sashes of the windows were so tilted as to form an outlet for the foul air. The employees, however, refused to have the windows open for fear of taking cold. Five manufacturers, whose establishments were inadequately ventilated, installed new ventilating systems.

Removal of Dust. — In 6 factories the need of protecting employees against dust was pointed out, and in 5 instances a number of emery wheels were provided with dust-removing devices.

Water-closets. — A large number of manufacturers made extensive changes to conform with the requirement of the law in regard to proper water-closets. One firm expended about $2,500 in installing new plumbing. Another firm commenced to install new water-closets throughout their mills. Orders for the provision of proper water-closets were issued to 23 firms.

Drinking Water. — Pure drinking water was found provided in all the factories visited. The water used in humidifiers in a few of the textile industries in the district was also pure.

Receptacles for Expectoration. — Seventeen of the 33 manufacturers to whom orders for the provision of sputum receptacles were issued complied with the orders.

First-aid Outfits. — Ten of the 26 firms ordered to provide medical and surgical appliances in their factories complied with the law.

Seats for Women. — As a rule, seats were found provided for women, but in 1 instance additional seats were ordered and provided.

Foundries. — Three foundries were inspected. In 1, conditions were found satisfactory; washing facilities and proper water-closets were ordered in another; in the third, a ventilator previously ordered was placed in the roof, new water-closets installed and a first-aid outfit provided.

Health of Minors in Factories.

Thirty-one hundred minors were seen and questioned. In 60 cases physical examinations were made because of tubercular family history, and 11 because of previous personal history. Of the 10 minors found in ill health but 1 was under eighteen years of age. Six were found to have tuberculosis and 4 heart disease. In each case the minor's parents were notified. None of the minors were found in departments in which processes dangerous to health were conducted, but 2 were exposed to possible unhygienic influences.

Tenement Hygiene.

All the rooms in tenements where work was done on wearing apparel were found to be clean. One hundred and forty-two licenses were issued. In only 4 cases were licenses refused.

Hygiene of Public Buildings.

The water-closet arrangements were found satisfactory in the 18 buildings visited. The ventilation in several amusement places was found inadequate.

Schoolhouse Hygiene.

Fifty-four inspections of schoolhouses were made in the city of Worcester. While in the main the ventilating and sanitary provisions were satisfactory, it was found necessary to issue orders to provide for changes in ventilation and water-closet provisions in 3 schools. Of 2 schools inspected in Millbury, 1 was found to be inadequately ventilated, and the attention of the school committee was called to this fact.

Inspection of Slaughterhouses.

Eighteen slaughterhouses were inspected, and in 4 instances it was necessary to issue orders for cleanliness, and for greater care in handling the refuse, to minimize the foul odors.

HEALTH DISTRICT NO. 12.

LEWIS FISH, M.D., *Fitchburg, State Inspector of Health.*

This district includes the city of Fitchburg, and the towns of Ashburnham, Ashby, Athol, Barre, Berlin, Bolton, Boylston, Clinton, Dana, Gardner, Hardwick, Holden, Hubbardston, Lancaster, Leominster, Lunenburg, New Braintree, Oakham, Paxton, Petersham, Phillipston, Princeton, Royalston, Rutland, Sterling, Templeton, Westminster, Winchendon and West Boylston.

The work of the year consisted of conferences with the local boards of health, investigations of contagious diseases and local nuisances, and of the inspection of factories and examination of minors in factories.

Diseases Dangerous to the Public Health.

All the towns in the district were visited and the local boards of health advised as to quarantine and disinfection of premises where diseases dangerous to the public health occurred, and as to the measures to prevent the spread of such diseases.

The local board of health of Barre called for the assistance of the State Inspector of Health in the investigation of a small outbreak of typhoid fever. An examination of the water of three wells used by all those who were ill

with typhoid showed it to be grossly polluted. Moreover, changes were suggested and carried out which changed the course of the drainage and protected the wells.

The board of health of Ashburnham was advised in the quarantine of a case of diphtheria in a family where there were seven other children. The case was strictly quarantined. The other children were given immunizing doses of antitoxin, and the sick child was not released from quarantine until release cultures were obtained. No other cases occurred in the family.

Other cases of diseases dangerous to the public health that occurred in the district were investigated as follows: —

Three children ill with scarlet fever in Boylston, all in the same family, attended school until two days previous to being taken ill. The board of health was advised to close the school for ten days, fumigate the schoolroom, and to destroy all books used by the children. All these suggestions were carried out and no further cases occurred.

Four cases of scarlet fever occurred in Leominster. The school attended by 2 of the sick children was closed for two weeks and thoroughly fumigated.

A case of typhoid fever was reported from a farm in Hubbardston. Strict quarantine measures were instituted, to prevent the spread of the disease by the dairy products.

Four cases of diphtheria in Ashburnham occurred in children who came on a visit from New Hampshire. Two of these cases proved fatal, and the wife of the undertaker who prepared the bodies for burial was taken sick with the disease shortly after. Proper precautions were taken to prevent the spread of the disease.

Outbreaks of measles were investigated in Gardner, Clinton and Sterling.

Between the 6th and 17th of June, 7 cases of typhoid fever were reported to the board of health of Fitchburg. Five of these cases took their meals at the same restaurant. The man supplying milk to this restaurant was buying it from ten different farmers. All the farms were looked into and no source of infection could be found on them. It was found, however, that a young man who was first taken ill waited on the table in the restaurant in his spare time. It is possible that this man was the source of infection to the others who took their meals at this restaurant. An investigation was also made of 16 cases of typhoid fever reported to the Fitchburg board of health during the months of September and October.

A small outbreak of typhoid fever was investigated in Winchendon and reported upon.

One case of typhoid fever was investigated in West Boylston.

An investigation was made of a dry goods establishment in Fitchburg, 3 of the employees of which were reported as being ill with tuberculosis. Nothing was found on the premises to suggest a common source of infection.

There was an outbreak of diphtheria among the children of a fresh-air camp at South Athol. Seven children out of the 130 were taken sick with the

disease. All proper precautions were taken to prevent the spread of the disease among the other children.

In portions of the district tuberculosis is now more generally reported than ever before. Between Aug. 1 and Oct. 5, 1908, there were more tuberculosis cases reported to the Fitchburg board of health than for any corresponding length of time since tuberculosis has been a notifiable disease.

No reports of cases of diseases dangerous to the public health were sent to the State Board of Health during the year 1907 from Ashby, West Boylston, Lunenburg, New Braintree, Paxton and Royalston. An investigation was made in all of these towns, with the following results: no records were kept by the boards of health of Ashby and New Braintree; no diseases dangerous to the public health were said to have occurred during the year at West Boylston and Lunenburg; two cases of diphtheria had been reported to the board of health of Paxton. The attention of all these boards of health was called to sections 51 and 52, chapter 75 of the Revised Laws, and they were requested to notify the State Board of Health within twenty-four hours after such diseases were reported to them.

Upon the request of the board of health of Berlin information and advice were given relative to the quarantine and care of children ill with measles.

The Clinton board of health, in conjunction with the Society for the Control and Care of Tuberculosis, established a day camp for their tubercular patients.

The attention of the boards of health of the district was called to section 2, chapter 503, Acts of 1907, relative to sputum receptacles in factories and workshops, and they were requested to make their requirements in accordance with this section. The boards of health of Athol, Fitchburg, Gardner, Hardwick and Leominster acted in the matter.

Court Case. — On August 1 the State Inspector of Health was informed by the local health authority of Sterling that William Hastings, who had been ill with measles, had removed the quarantine sign and was going about without their permission. Court proceedings were instituted. Conviction was obtained and a fine of $10 was imposed upon Mr. Hastings.

Local Nuisances.

Several conferences were held with the board of health of Lunenburg relative to the existence of a stagnant pool which the cattle on a farm used for drinking purposes. No action has as yet been taken in the matter.

The board of health of Royalston abated a nuisance consisting of dirty privies and collections of filth.

Nuisances of accumulation of filth on private property were abated by the board of health of Hardwick.

A local nuisance, consisting of filth and bad drainage, was called to the attention of the board of health of Hubbardston. This matter is still pending.

The attention of the board of health of South Barre was called to a number of local nuisances, consisting of inadequate cesspools, dirty privies and

improper protection of the springs from which drinking water was taken. Suggestions were made to the board of health as to remedying these conditions, and improvements are being carried out as fast as possible.

The attention of the Gardner board of health was called to a stream of water polluted by sewage from a number of privies. This stream is used by a herd of cattle for drinking purposes. No action has been taken in the matter.

Suggestions to improve drainage, to replace wooden drain pipes by metal ones and to keep the privies in better condition were made to the owners of the property at Spring Village, Winchendon. These matters were also brought to the attention of the board of health of Winchendon. The suggestions were complied with.

Factory Hygiene.

During the year 162 factories were inspected. In 18 no violations of the law were found. The attention of manufacturers was called in writing to 117 violations of the law, and verbally to 84. Of the 158 orders complied with, about half related to the provision of sputum receptacles. Twenty first-aid outfits were provided, and in 2 factories seats for women.

Cleanliness. — Improvement in cleanliness was made in 15 establishments.

Light and Ventilation. — The light in the factories visited was in general satisfactory. All processes which required good light were conducted near the windows. In the center of large rooms incandescent bulbs were in use.

Ventilation was markedly improved in 8 establishments, and in 11 instances employees were better protected against dust generated in the course of manufacturing processes.

In only 1 factory were mechanical means for ventilation provided. In all processes of manufacture where vapor or gases are produced hoods and exhausts were usually provided for their removal. The basement rooms of the factories were in general found to be poorly lighted and ventilated.

Drinking Water Supply. — A supply of pure drinking water was ordered and provided in 2 factories.

Artificial Moisture. — In 1 factory the humidity was better regulated.

Water-closets in Factories and Mercantile Establishments. — Proper water-closets were provided in 19 factories, and orders were issued for proper closets in 3 mercantile establishments.

Hygienic Conditions. — Of 79 factories visited in different industries, the hygienic conditions in 15 were sanitarily ideal, in 43 good, in 18 moderately bad, and in 3 distinctly bad.

Foundries. — One of two orders issued to provide for proper washing facilities in foundries was complied with.

Industrial Hygiene. The Relation of Industries, Processes or Unhygienic Conditions to Health.

Chair Factories. — The large factories were found to be provided with efficient blower systems, which carried the dust into the boiler room. In the smaller establishments the dust-removal systems were inadequate, and in 1

factory no protection for the removal of dust was found. The ventilation of the paint rooms in these factories was found to be inadequate. Drinking water was not easily accessible to all the employees, inasmuch as only one faucet was provided in the basement of the building. There were no washing facilities in any of these factories.

Tub and Pail Factories. — In the tub and pail industry the process of turning and sanding the tubs gives rise to great quantities of dust. A tub is placed on a mould and fastened, and then rapidly revolved. The planes are now brought down upon the tub, causing an enormous amount of heavy dust. A lever covered with several layers of coarse sandpaper is then brought in contact with the tub, giving rise to large quantities of fine wood and sandpaper dust. Minors are commonly exposed to this dust, since the man in charge of the work employs a boy as helper.

Piano and Piano Case Factories. — These factories were provided with efficient dust-removal systems. The ventilation in many of the rooms was inadequate. In the paint and varnish rooms all the windows were closed, to keep the air still and free from dust. In the veneering room the employees were exposed to a high temperature (95° to 100° F.).

Reed Working Factories. — Two of the 5 reed working factories showed lack of cleanliness. Collections of filth and rubbish were noticed in various parts of the rooms and stairways. Water-closets situated in the basement were old, dirty and in poor repair. In the basement of one of these factories the metal working department was located. Two forges were in operation, from which volumes of smoke filled the basement and the rooms above.

Shirt Factories. — Two shirt factories visited were found excellently lighted and ventilated. The wash rooms in the basement had cement floors, with good drainage. The girls working in the ironing rooms were found exposed to high temperatures and to possible carbon monoxide and carbon dioxide gas, produced in the process of heating the iron with the illuminating gas. The work necessitated their standing continuously, and many assumed a stooping position over their work. They were pale, and not so healthy looking as the girls from the other department.

Horn and Celluloid Shops. — Many of these shops are conducted in small, poorly lighted and poorly ventilated buildings. In some shops machines were used for the polishing of cheap horn hairpins. This process caused a great deal of dust, and in only 1 establishment was there an exhaust system for the removal of dust. The fumes of acetic acid, which arise in the "dipping" process, were found to be taken care of by means of hoods and exhaust fans. Nevertheless a strong odor of acetic acid was noticeable in and about the workrooms where this process was carried on.

Cotton Mills. — With 1 exception all the mills have provided modern humidifiers. In one mill the "steam-vapor-pot" system was used. In this mill no thermometers or hygrometers were observed. The weaving machines were of the old style, necessitating the drawing of the filling through the shuttle eye by the mouth. In 1 mill, where coarse cotton yarn was manufactured, the card room was found to be dusty and poorly ventilated.

Paper Mills. — The sorting room of 1 paper mill was found well lighted and well ventilated. The process of sorting the old paper did not give rise to any dust. The duster and thrasher were well covered, and provided with an exhaust pipe and a blower.

Health of Minors in Factories.

During the year 2,945 minors were seen and questioned. Seventy-five minors were carefully examined, 35 because of a tubercular family history, 10 because of previous personal history and 40 because of the minor's appearance. Only 10 minors were found to be in ill health, 5 of whom were under eighteen years of age, — 3 girls and two boys. The conditions of ill health were: 3 cases of tubercular adenitis, 3 marked anæmia, 2 laryngitis, 1 bronchitis and 1 functional cardiac disease. Tubercular involvement was suspected in 1 of the laryngitis cases and in the bronchitis case. Five of the minors found in ill health worked in a cotton factory, 4 in the ring spinning and 1 in the weaving department.

In 6 cases it was deemed advisable to notify the minor's parents relative to a change of employment. Four minors stopped work and secured other employment, and 2 were given lighter and easier work. One minor was to be watched by the foreman.

Hygiene of Schoolhouses and Public Buildings.

Five school buildings were inspected in Fitchburg. In 2, orders were issued for the provision of proper water-closets. These orders were complied with.

An order was issued to the authorities of Hubbardston to provide adequate ventilation and proper water-closets in one of their schoolhouses. This order was annulled by the local board of health on the ground that the town was not in a position now to go to the expense of making the required changes.

Other schoolhouses were inspected in Petersham, Oakdale, North Dana and Boylston.

Three theaters inspected in Fitchburg were found adequately ventilated.

Inspection of Slaughterhouses.

Eight slaughterhouses were inspected, 3 in Fitchburg, 2 in Princeton, 2 in Westminster and 1 in Hubbardston. The killing rooms were found dirty in all of them.

HEALTH DISTRICT NO. 13.

HARVEY T. SHORES, M.D., *Northampton, State Inspector of Health.*

This district includes all of Franklin County, and all of Hampshire County excepting the towns of Huntington, Middlefield and Worthington.

Boards of Health, and Diseases Dangerous to the Public Health.

In 12 of the towns in the district there are boards of health. In the other 34 towns the selectmen act as boards of health, and, as a rule, have little knowledge of their duties pertaining to health matters. When a question was addressed by the State Inspector of Health to the various health authorities, to find out what towns require negative cultures before releasing diphtheria cases from quarantine, it was found that only 3 towns in the district required negative cultures. One board of health replied that they "usually do;" one, that they "did in one case;" many, that they "never had occasion to make such requirement;" while a number of so-called "boards of health" did not understand the meaning of the question.

Fumigation of premises following certain communicable diseases is now carried on more regularly in all the towns, either by the attending physician, by the undertaker or by the agent of the board of health.

In 15 towns in the district school children were not required to be vaccinated.

Outbreaks of scarlet fever were investigated in Northfield and in Northampton, an outbreak of diphtheria in Southampton, and an outbreak of typhoid fever in Belchertown and Hadley. These were all reported upon. An outbreak of infantile paralysis in Shelburne Falls and in Turners Falls was investigated, but this investigation is not yet completed. A number of farms in the vicinity of Gibb's Crossing and Gilbertville were inspected in connection with a number of cases of scarlet fever that occurred in Cambridge. The findings were reported upon.

Local Nuisances.

A nuisance consisting of a dirty privy was brought to the attention of the board of health of South Hadley.

Factory Hygiene.

During the year 128 factories, representing more than 25 different industries, were visited. Sixty-six orders and suggestions were given for changes in compliance with the law. In 11 factories, where reinspections were made, 7 of the orders were complied with.

Light and Ventilation. — Light and ventilation were found satisfactory in all the factories.

Removal of Dust. — The removal of dust was found inadequate in several factories where small tools were made. Likewise in the cutlery factories, for although the emery wheels were provided with hoods and suction pipes, they were not used, as the men claimed that they obstructed the light and interfered with their work.

Sputum Receptacles. — Only a few of the factories visited were found provided with sputum receptacles. In those factories where the manufacturers strictly enforced the antispitting law such receptacles were not needed.

In a number of factories, however, there was abundant evidence of expectoration.

Drinking Water. — All the factories were found supplied with pure drinking water.

Cleanliness. — The cleanliness of the factories and water-closets, while in the main satisfactory, could, in many instances, be greatly improved.

Foundries. — Wash rooms were provided in all of the 11 iron foundries visited. These rooms, however, were quite dirty, the floors being wet and muddy. In 2 brass foundries there were no washing facilities provided.

Hygienic Conditions. — The general hygienic conditions in the 128 factories and other establishments visited were sanitarily ideal in 16, good in 61, moderately bad in 39 and distinctly bad in 12.

Health of Minors in Factories.

During the year 2,506 minors were seen and questioned, and more than 100 physical examinations were made; 44 minors were found in ill health, 28 of whom were under eighteen years of age. In each case the employer promised to favor the minor, and 6 of the minors had their work changed. Of the 9 instances where parents were notified relative to the ill health or physical unfitness of the minor, 5 minors stopped work and 1 consulted a physician. One minor, with a serious disease of the heart, was advised to leave work.

Other conditions of ill health or physical unfitness found among the minors were: anæmia and ill nutrition, 15; round shouldered and flat chested, 7; underdeveloped, 4; emaciation, 4; tuberculosis, 2 (1 died three months later): asthma, 2; nervous prostration, 2; inflammation of eyes, 2; and 1 each of exophthalmic goiter, chronic appendicitis, tubercular hip, throat affection and general debility.

Of the minors found ill with tuberculosis, 1 worked in a dyehouse and the other in a room where the process known as "wet stretching of silk" was conducted. One minor who was found tubercular last year, and was then advised to give up work, went out on a farm and was under a physician's care. She returned to work in July, 1908, apparently cured.

Adult Employees in Ill Health.

One adult employed in a knitting mill was found suffering from tuberculosis. He went to Rutland. Another adult was referred to the State Inspector of Health. This man was a Polander and lived with his brother in dirty, overcrowded quarters. He was suffering from an advanced stage of tuberculosis, which made him unsuitable as a candidate for Rutland. He was advised to enter the State poorhouse.

Hygiene of Schoolhouses and Public Buildings.

The attention of the authorities of Deerfield was called to the poorly ventilated condition of the Center School building. An order was issued to the school committee of Belchertown that the addition built to the present school building must be properly ventilated.

The railroad station, the town hall and the library in Easthampton and Northampton were inspected and were found in good sanitary condition.

Inspection of Slaughterhouses.

Of the 2 slaughterhouses inspected 1 was found in an unsanitary condition.

Health District No. 14.

Herbert C. Emerson, M.D., *Springfield, State Inspector of Health.*

This district includes all of Hampden County, and, in addition, the towns of Huntington, Middlefield and Worthington.

Consultations with Local Boards of Health.

Forty consultations were held with representatives of the boards of health of 25 cities and towns relative to the health of towns, the occurrence of diseases dangerous to the public health, the methods of boards of health in guarding the public health against tuberculosis and other infectious diseases, and the statute requirements for first-aid appliances and sputum receptacles in factories and workshops.

At least 8 different methods of disinfection were found to be in use. In some cases the work was done free of charge, in others at the expense of the householder; the rooms in some instances were sealed, while in others they were simply closed; and the length of time in which the rooms were permitted to remain under the influence of the disinfectant varied from "no specified time" and "two hours," up to, in one instance, "four to twenty-four hours" and in another "forty-eight hours." Most of the reports showed that there was no definite time during which the rooms were closed.

Diseases Dangerous to the Public Health.

There were no epidemics of diseases dangerous to the public health during the year, although there were small outbreaks of typhoid fever in Agawam, Palmer and Westfield, and scarlet fever prevailed to an unusual extent in Chicopee.

Tuberculosis. — A gradual improvement in reporting cases of tuberculosis was noted. This is shown by the following table: —

	Six Months ending June 30, 1907.	Six Months ending Dec. 31, 1907.	Six Months ending June 30, 1908.
Springfield,	-	18	50
Holyoke,	-	11	22
Chicopee,	10	11	13
Palmer,	-	-	1
Westfield,	2	8	11
Monson,	-	5	4
Brimfield,	-	1	-
	12	54	101

It thus appears that 3 cities and 4 towns reported 12 cases of tuberculosis during the six months ending June 30, 1907, 54 cases during the six months ending Dec. 31, 1907, and 101 cases during the six months ending June 30, 1908. From 19 towns no cases of this disease were reported during the entire period of eighteen months.

Agawam: Typhoid Fever. — From the latter part of July to the middle of September there were 19 cases of typhoid fever in Agawam. An investigation was made of these cases with a representative of the local board of health, and no common cause could be found for their origin. Seven cases occurred in one family, the later cases undoubtedly being secondary. Fourteen cases lived in six houses which, although separated from each other, were upon the same street, which was a main country road. While the investigation did not show the carrier of the infection either through the milk supply or by means of a meat and vegetable peddler supplying many houses in this district, the distribution of the cases pointed to some local carrier. Nearly all the houses took their drinking water from wells, which were usually about 50 feet from the earth closet.

Chicopee: Scarlet Fever and Diphtheria. — Cases of scarlet fever and diphtheria were reported in unusual numbers in Chicopee, as follows: —

	Six Months ending June 30, 1907.	Six Months ending Dec. 31, 1907.	Six Months ending June 30, 1908.
Scarlet fever,	43	116	120
Diphtheria,	15	55	30

Eighty-five cases of scarlet fever were reported for the year ending June 30, 1907, and 236 cases for the year ending June 30, 1908. In the latter part of 1907, at the request of the local board of health, several consultations were held relative to the spread of this disease. A more rigid investigation and oversight of reported cases were suggested. In May, 1908, a consultation was requested by the local board of health relative to an outbreak of scarlet fever among persons having a common milk supply. Investigation revealed the fact that 2 children had scarlet fever in the family of a farmer supplying milk to the peddler upon whose route new cases of this disease were constantly being reported. These cases had not been recognized as scarlet fever, and later a third child in the family contracted the disease. The milk from the dairy was not brought into the house, but the farmer's wife cared for the children and also washed the milk pails, cans and the strainer cloths. The local board of health prohibited the sale of milk from this dairy and in a short time the outbreak was over.

Palmer (Bondsville): Typhoid Fever. — In November, 1907, there was a sudden outbreak of typhoid fever in the village of Bondsville (Palmer) among the mill operatives. About 20 cases appeared in families who had a common milk supply. The milk served to these families by the peddler was

secured from a neighboring farm, where a few weeks previously one of the members of the family had been ill for two or three weeks. The history of the cases suggested "walking typhoid," but no diagnosis had been made. The sanitary condition at this dairy was extremely bad, and the person who cared for the patient also milked the cows. The examination of the blood of this person who had been ill, some weeks after his illness, at the time of this epidemic, showed a positive Widal reaction. No further cases were reported after the milk supply was shut off.

Westfield: Typhoid Fever. — During August and the early part of September 23 cases of typhoid fever were reported to the local board of health. An investigation was made of these cases, with a representative of the local board of health, from which it appeared that 3 cases were probably imported and 1 case was not typhoid fever. Of the remaining 19 cases, 4 were in one family, 3 of which may have been secondary cases. One of the earliest cases occurred in a woman who did the housework in the family of a dairyman. As soon as this fact was ascertained by the local board of health the sale of this milk was stopped. Conditions at the dairy were found to be decidedly unsanitary. Investigation seemed to show that the infection of 6 cases might be traced to this dairy, and it is reasonable to suppose, from the disposition made of the milk in question, that several other cases may have received their infection through this milk. The outbreak ceased about two weeks after the sale of this milk was stopped. Investigation was also made of a case of typhoid fever occurring in a house adjacent to one of the Westfield reservoirs, of a suspected case of "walking typhoid" and of the sanitary condition of various premises on the watershed. Although several possible sources of pollution of the Westfield water supply were found, it did not appear that there had been contamination of the water from any of these cases of typhoid.

Local Nuisances.

Holyoke. — The attention of the local board of health was called to a nuisance consisting of standing water near a schoolhouse.

Longmeadow. — A nuisance in Longmeadow consisting of a cesspool overflowing on private and public property was investigated, and the facts were referred to the local board of health.

Palmer. — A nuisance caused by an open drain in Palmer was investigated, with a representative of the local board of health, and measures were taken for its abatement.

Southwick. — After a consultation with the local board of health, the State Inspector of Health inspected the conditions about the shores of Lake Congamond in Southwick, where an ice company annually harvests a very large quantity of ice, about 175,000 tons. The sanitary arrangements for the employees which numbered from 500 to 700 during the season, were found to be extremely bad. While the sleeping quarters for these men were cramped and overcrowded, entirely inadequate sanitary facilities were furnished, and these were in an execrable condition. Orders were given to the company to provide proper sanitary facilities for their workmen.

Factory Hygiene.

One hundred and seventy-four factories and workshops were inspected, 27 of which showed no violation of the statutes. Written orders were sent to 135 manufacturers whose establishments showed violations of the statutes; 97 of the manufacturers complied with the orders. Verbal orders were given to 30 manufacturers, 26 of whom met the requirements. The total number of orders issued in accordance with the statute requirements was 271, as follows: sputum receptacles, 132; closets, 63; first-aid appliances, 46; pure and fresh water, 8; cleanliness, 6; removal of dust from emery wheels, 5; light, 4; protection from dust, 3; toilet facilities for foundry, 3; women's seats, 1.

Industrial Hygiene. The Relation of Industries, Processes or Unhygienic Conditions to Health.

Paper Mills. — The paper mills visited were large, well lighted and adequately ventilated, and furnished employment under satisfactory conditions. The rag sorting rooms were productive of more or less dust and dirt, depending upon the class of rags used. The rag rooms of a few mills using clean stock only were practically free from dust and dirt. The rag dusters and cutters were universally provided with dust-removal apparatus with suction, but in many cases the hoods were deficient in size. The cleanest rag rooms were found in those mills in which these machines were placed outside the rag sorting rooms. The rag sorters are all women, mostly of middle age. Inquiry in all the mills showed that sickness among them was of rare occurrence.

Coated and Glazed Papers. — Factories making coated and glazed papers presented one objectionable and unavoidable condition in the coating room. The paper is run off the roll through a coating machine, and is then automatically carried down a long runway, heated with steam to dry, and then returned to be rewound. The operators, all men, were employed solely at the end of the room where the winding and coating machines were located. Most of the rooms had windows on three sides which furnished ventilation, but throughout the runway the windows were closed, to maintain the requisite heat and to keep out the dust; consequently, the heat in the work end of the room was excessive, varying from 96° to 100° F. Another workroom of high temperature was that where large steam-heated cylinders were revolved. In 1 mill it was stated the temperature of this room was never supposed to go over 114° F.; it was 112° F. at the time of inspection. Aside from this, work in the coated paper factories and the papeterie and envelope factories was not accompanied by objectionable conditions. The workrooms were large, light, and well ventilated, and there were good toilet facilities.

Machine Shops. — The machine shops in general were found to be poorly lighted, especially where heavy machinery was in use. The finishing and small tool rooms were generally well lighted and ventilated. More expectoration was noticed in machine shops than in other workshops or factories.

The toilet rooms were unusually clean and well kept in many of these shops. One large shop was noticeable for its general cleanliness in all departments; buffing and grinding wheels were carefully fitted with hoods and suction apparatus; sputum receptacles were provided in the various rooms; and the closets were well kept.

Foundries.

Iron. — Six iron foundries were inspected, 2 of which were high posted, well ventilated and lighted, and had satisfactory toilet facilities. One foundry was very poorly lighted and ventilated, with toilet facilities consisting of an outdoor vault, in a very unsanitary condition, at some distance from the factory, and with no room provided for the workmen to change their clothes in. Orders were given to install proper toilet facilities for this foundry, but, owing to the fact that the foundry was practically shut down, the orders have not yet been complied with. In 3 foundries, although the grinding machines were provided with a dust-removing device, the apparatus was found to be filled with dust and not in working order. There was also a great excess of dust in one tumbling room. Orders were given to provide efficient dust-removal apparatus. Two iron foundries had large, closed rooms in which a sand blast was used for cleaning castings. The operator wore a respirator and a mask, covering his entire head, while using the apparatus. A large pipe connected with a fan removed a portion of the sand and dirt outside the building.

Brass. — Three brass foundries were found to be well ventilated, with satisfactory arrangements for quickly getting rid of the zinc fumes and gas. One foundry used a battery of four oil furnaces, protected by suitable hoods.

Drop Forge Factories. — Four drop forging plants were inspected. Steel bars are heated in oil or gas furnaces and then placed in heavy drop forge machines, which stamp out the tools. Drop forging rooms are very hot near the furnaces, but the rooms are usually much open to the weather and are hence subject to extremes of heat and cold. These rooms are usually dark, with dirty floors, and there is considerable dust and smoke constantly arising. One drop forging plant was in a most unsanitary condition, with the drop forge room dark and dirty, and all other rooms overcrowded; no suction was applied to the emery wheels; and toilet accommodations, which were insufficient for the number of men employed, were very unclean. The company has vacated these quarters and has moved into a new, modern, well-equipped building. A drop forge room of another plant was paved with brick, and was well lighted and well ventilated; suction was applied to all polishing and grinding machines; sputum receptacles were furnished throughout the factory; and the toilets were unusually clean. The walls were everywhere whitewashed, and the general condition was excellent.

Needle Factory. — One needle factory was inspected which was a large, well-lighted building, although not a recent structure. Suction was applied to all dry grinding wheels, sputum receptacles were furnished, and the factory was clean throughout. The toilets were in fair condition, but of very

old type and unsatisfactory. A suggestion for new toilets was made and an entirely new system was introduced.

Wire Works. — Two wire drawing establishments were inspected. The coating room of one establishment had a considerable amount of lime dust in the air, but in the other factory the room was much cleaner and freer from dust. One factory was well provided with fans in the annealing and tempering rooms, while the other had fans and ducts for removing the fumes. Considerable expectoration was found in both factories.

Cotton and Woolen Mills. — The cotton and woolen mills visited were for the most part clean, and appeared to be well ventilated, but the light was somewhat interfered with by low ceilings and small windows.

Rug Making Shops. — Rugs were found to be made from old carpets by means of hand looms. The carpets were first cleaned, then cut into strips. They were then put through a fraying machine, which roughened the two edges ready for weaving. Much dust was caused by all the operations save the weaving. One shop had a tight room, which had a revolving cylinder, for cleaning the carpets, and ducts with suction were provided for removing the dust from the fraying machines. The walls of this shop were whitewashed, the floor was clean, the ventilation was adequate, and the air was comparatively free from dust and dirt. In another shop, where the same work was carried on, the carpets were cleaned in the open room, which was dirty and full of dust; the fraying machine was very poorly equipped with apparatus for removing the dust, which was carried into a corner of the room into a loose box of old boards and carpets. The room was dark, and the conditions for work decidedly unsanitary. In compliance with orders issued to the proprietors of this shop many improvements were made.

Carpet Factory. — One carpet mill was inspected and was found to be clean, light and well ventilated, and free from dust throughout.

Waste Factories. — The waste mills showed very little dust aside from the "fly." A dust machine with suction was used for waste requiring this treatment.

Candy Factories. — One candy factory was well lighted and ventilated, but the floors and much of the furniture were in a decidedly unclean condition. The toilets, however, were unusually clean and well cared for. Two other factories were clean in every way.

Electrical Works. — An electrical insulation workshop presented an objectionable condition in the amount of heat and steam vapor present in the steam press room, used for pressing the material into shape. Fans were provided for ventilation. The nature of the processes employed maintains an undesirable condition of the atmosphere.

Wood Working Shops. — Four large shops were well lighted, except in one, where artificial light was used in the basement. Excellent suction for removing fine dust was found in 3 shops, although much of the coarse sawdust and shavings were still left on the floors. One large shop was noticeable for its roomy arrangement for machinery and its ample light.

Button Factories. — Manipulation of the vegetable ivory used in making

buttons gives rise to a large amount of coarse sawdust, which is difficult to remove by suction. One plant had spent a large amount of money in trying to adapt a blower system to its sawing machines, without success. The machines, however, which cut out the buttons produce fine dust, which is adequately removed by a suction apparatus.

Laundries. — The laundries were generally overcrowded and poorly lighted. In 1 laundry the conditions were distinctly bad, and artificial light had to be used much of the time. So closely crowded was the machinery in this laundry that it was difficult to move about the rooms. A ventilating fan and electricity supplied air and light to a most important workroom, which otherwise would have had very little ventilation and light. The proprietors intend to vacate these rooms as soon as their new laundry is completed. In another laundry the rooms were large and airy, and the machinery was placed so that there was no overcrowding. One laundry, employing 14 men and 8 women, had but one closet for both sexes. Upon an order from the State Inspector of Health an additional closet was installed.

Straw and Felt Hats. — The factory visited was well lighted, adequately ventilated and kept in excellent sanitary condition. The bleachery and small spelter foundry presented no objectionable features. The pulling room, with its steam presses, showed an excess of hot vapor, but most of the excess steam was removed by ducts.

Corundum Wheel Factories. — Two factories making corundum wheels were inspected, 1 of which was small, employing but 10 men, but clean, well lighted and well ventilated throughout. The only dust in this factory came from the truing up and smoothing processes, but the amount was not great. In 1 large factory much dust was found in the room where the dry clay was ground, and from the rooms where the wheels were finished. Although no dust-removal apparatus was in use, the company were considering how best to install suitable dust-removal machinery.

Emery Grinding. — Two small emery grinding establishments were visited. The rooms where the rolling and grinding were done were large, well lighted and well ventilated, but a large amount of dust was present when the machinery was running. It was stated in 1 factory that the material was dampened to avoid as much dust as possible in the grinding process.

Fiberloid. — One large factory was inspected in which the operations incident to the industry were carried on in twenty-two detached buildings. The plant is modern, and is well lighted and ventilated and clean throughout. There was one room in which the hygienic conditions were bad, and this was the "acid room." Tissue paper is torn into strips, then taken to the acid room, where a mixture of acids is poured upon it in stone jars. The mixture is then freed of most of the acid solution and the material washed. It is still further washed, dried and mixed with wood alcohol and camphor. The acid room was provided with two 36-inch fans, revolving five hundred times per minute, for removing the fumes. However, the fumes were by no means entirely removed, and from time to time clouds of nitrous fumes were given off. Two large tanks of water were provided in this room, to be used in case

of accident. The floor is kept constantly wet, and most of the employees wear cloths wrapped about their feet on account of the action of the acid. The windows and doors of this room are usually kept closed, in order to get full advantage of the suction from the ventilating fans. The room in which the final mixture is kneaded and rolled is well supplied with hoods and suction to remove the alcohol and other fumes. In many departments the air is screened before being admitted to the rooms, to remove all dust.

Hemp and Jute. — One large hemp and jute establishment, employing nearly 3,000 persons, was found to be well kept throughout. The toilets, all of which had outside ventilation, were in good condition. The work was carried on in several isolated mills, 1 of which employed upwards of 800 persons. The materials used in the manufacture of bagging, twine and cordage are jute, flax and hemp. All the raw material is first moistened and run through breakers. The mills using jute alone showed much less dust than those using hemp or a mixture of hemp and jute. After the material is moistened it is then put through the breaker cards, which give rise to large quantities of dust. In but one room, however, was the dust extreme in amount. In this room 2 employees were protecting their mouths and noses with a bunch of the raw material. Arrangements are now in progress to install a dust-removal apparatus for these breakers. After the material leaves these machines it is put through the finishing cards, where more or less dust is generated, particularly when hemp is used. In 1 mill, using jute and hemp, the breaker cards were all fitted with an efficient suction apparatus, which took away practically all the dust and lint from the machine. The spinning and weave rooms were large, well ventilated and free from dust, although practically all rooms showed more or less "fly." As a whole, the employees appeared well. It was stated that the mill population was usually quite free from sickness, and that tuberculosis was rare. There was a modern, well-equipped hospital in one of the company's buildings, in charge of the Hospital Association, in which sick persons or accident cases could receive prompt treatment.

Health of Minors in Factories in Relation to the Industry.

A total of 4,881 minors were inspected. Of this number, 706 were inspected without conversing with them, while passing through the factory. As all appeared to be in good health no further examination was made. The remaining 4,175 minors were inspected, of which number 2,282 were females and 1,893 males, classified according to age as follows: —

	Age.							Totals.
	14	15	16	17	18	19	20	
Males,	106	193	254	351	354	375	260	1,893
Females,	132	215	307	411	435	434	348	2,282
Totals,	238	408	561	762	789	809	608	4,175

The average age of both male and female minors was seventeen and a half years, and nearly 6 per cent. of the minors were fourteen years of age and 15 per cent. were under sixteen years of age. Questions were asked as to their health, the length of time they had been at work and the health of the nearest relatives. A physical examination was made of minors whose appearance suggested ill health, and of all minors fourteen years of age, in 2 large establishments employing 5,300 persons.

Thirty-four hundred and fifty-eight minors were still further questioned as to whether any members of the minor's family had had tuberculosis, and those minors with tubercular histories were also subjected to a physical examination. Seventy-five minors were found to have tubercular histories, and upon examination no signs of tuberculosis were found in any, with the possible exception of 1, who has since been under observation. The family history of the 75 minors referred to showed that the mothers of 25, fathers of 19, sisters of 13 and brothers of 11 died from tuberculosis, while active cases of tuberculosis were present in the families of 7. Inquiry showed that great care was taken in many families to prevent the spread of the infection, and advice was given to those minors in whose family tuberculosis now exists. In the case of 1 minor, who has been under observation since the first examination, the family history showed that the mother, who died of tuberculosis, was one of 19 sisters, 16 of whom died of the same disease. None of these minors were engaged in occupations productive of dust, and most of them were employed under excellent sanitary conditions.

Two hundred and seventy-one minors were subjected to a physical examination, of which 148 appeared to be in good health and 123 were found defective, classified as to age, sex and condition as follows: —

	Males.							Females.							Totals.
	Age.							Age.							
	14	15	16	17	18	19	20	14	15	16	17	18	19	20	
Marked anæmia,	11	2	3	5	2	1	1	12	-	6	4	7	2	-	56
Poor development,	8	4	10	8	2	-	2	6	1	2	3	3	2	-	51
Enlarged tonsils and adenoids,	-	1	-	-	-	-	-	1	1	1	-	1	-	-	5
Heart disease,	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Profound anæmia,	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Spinal disease,	-	-	-	-	-	-	-	-	2	-	-	-	1	-	3
Rachitic,	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Tuberculosis,	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Enlarged cervical glands,	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Deafness,	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Goiter,	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Tuberculosis suspect,	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Totals,	21	7	13	14	4	1	3	19	5	9	9	12	6	-	123

Hemp and Jute Mills. — Eight hundred and six minors were employed in this factory, of whom 317 were males and 489 females. The greatest amount of dust came from the breaker carding machines, in which hemp alone or hemp and jute were being treated. Although this material was moistened before being put into the machines, great quantities of dust were given off. Four male minors were exposed to an extreme degree of dust in a room where hemp and flax were put through the breaker cards; 1 minor, twenty years of age, spread the raw material on the travelling sheet, feeding the cards; 3 minors, twenty, eighteen and fifteen years of age, cleaned and oiled these machines. Although constantly exposed to large quantities of dust, the minors appeared to be well, although most of them were anæmic, and had been working here for two to three years. One hundred and seven minors were employed in rooms where jute and jute and hemp were similarly treated, where the dust was considerable in amount, but it was not so great as in the room just mentioned. The occupations of these minors consisted in feeding the raw material into the carding machines, taking away the product from the rear of the machine and cleaning the machines. Twenty-nine were females and 78 were males, classified by age as follows: —

	Age.							Totals.
	14	15	16	17	18	19	20	
Males,	8	7	7	17	11	18	10	78
Females,	-	-	3	4	4	9	9	29
Totals,	8	7	10	21	15	27	19	107

Of these minors 10 were examined, and 8 were found defective and 2 in good health, all of whom were males, as follows: —

Condition.	Age.	Weight (Pounds).	Height.	
			Feet.	Inches.
Good health,	14	94	5	-
Poor development,	14	76	4	7
Poor development,	14	65	4	7
Anæmia,	14	79	4	10¼
Anæmia,	14	87	5	-
Anæmia,	14	92	5	1
Anæmia,	14	102	5	1
Anæmia,	14	106	5	2
Good health,	15	82	5	3
Poor development,	17	92	4	9¼

The remaining 695 minors were employed chiefly in spinning rooms (47 males, 334 females), weave rooms (112 males, 22 females), twine finishing rooms (22 males, 38 females), and various other duties (54 males, 66 females), which were not accompanied by dusty processes.

Of the 381 minors in the spinning rooms a physical examination was made of 98; of these, 57 were found to be well and 41 defective. The following shows the physical condition, age, sex, weight and height of the latter: —

CONDITION.	Sex.	Age.	Weight (Pounds).	Height.	
				Feet.	Inches.
Anæmia,	Female,	14	80	4	9½
Anæmia,	Male,	14	85	5	1
Anæmia,	Female,	14	88	4	11
Anæmia,	Female,	17	92	5	8
Anæmia,	Female,	17	93	5	½
Anæmia,	Female,	14	94	5	2
Anæmia,	Female,	18	95	5	½
Anæmia,	Female,	19	96	5	–
Anæmia,	Female,	14	98	5	11
Anæmia,	Female,	14	98	5	8
Anæmia,	Female,	14	100	5	½
Anæmia,	Male,	18	102	5	1
Anæmia,	Female,	17	105	5	2
Anæmia,	Female,	16	108	5	2
Anæmia,	Female,	16	108	5	8
Anæmia,	Male,	18	108	5	4
Anæmia,	Female,	18	110	4	11
Anæmia,	Female,	18	115	5	1
Anæmia,	Male,	17	122	5	5½
Profound anæmia,	Female,	17	111	5	5½
Tuberculosis,	Female,	17	75	4	11½
Enlarged cervical glands,	Female,	18	76	5	1
Mouth breather,	Male,	15	87	4	11½
Mouth breather,	Female,	15	84	4	9
Mouth breather,	Female,	16	106	4	11½
Poor development,	Male,	14	68	4	4½
Poor development,	Female,	16	65	4	10
Poor development,	Male,	14	70	4	4
Poor development,	Female,	14	70	4	7
Poor development,	Male,	15	71	4	9
Poor development,	Female,	14	76	4	8
Poor development,	Female,	17	77	4	7½
Poor development,	Female,	16	76	4	10½
Poor development,	Female,	15	77	4	8
Poor development,	Male,	14	78	5	–
Poor development,	Male,	16	80	4	8
Poor development,	Female,	16	85	5	1
Poor development,	Male,	20	88	4	11
Poor development,	Female,	19	91	5	1½
Poor development,	Female,	19	93	5	1½
Poor development,	Female,	18	96	5	2

Defective minors in other departments: —

CONDITION.	Work.	Sex.	Age.	Weight (Pounds).	Height.	
					Feet.	Inches.
Poor development,	Office,	Male,	17	86	5	1½
Poor development,	Office,	Male,	16	76	4	8
Poor development,	Weave room,	Male,	14	66	4	5½
Poor development,	Weave room,	Male,	14	73	4	11
Poor development,	Weave room,	Male,	14	78	4	7½
Poor development,	Weave room,	Male,	17	85	5	1
Poor development,	Weave room,	Male,	17	86	5	1
Poor development,	Weave room,	Male,	16	86	4	9
Poor development,	Weave room,	Male,	16	86	4	8½
Poor development,	Weave room,	Male,	16	88	4	9½
Poor development,	Weave room,	Male,	16	89	4	10½
Poor development,	Weave room,	Male,	17	94	4	9
Anæmia,	Weave room,	Male,	14	76	4	11
Anæmia,	Weave room,	Male,	16	95	5	–
Anæmia.	Weave room,	Male,	17	98	5	–
Mouth breather,	Weave room,	Female,	18	95	4	9

All the minors fourteen years of age were examined, and the averages of their weights and heights were found to be as follows: —

	Males.			Females.	
	Weight (Pounds).	Height.		Weight (Pounds).	Height.
		Feet.	Inches.		Feet.
Good health, ...	93	5	-	95	5
Defective, ...	79	4	9	87	5

Cotton Mills. — One thousand one hundred and fifteen minors were employed in cotton mills, of which 642 were females and 473 males. The mills were clean throughout and were provided with adequate toilet facilities. The light and ventilation were fair in all the mills, good in some and nowhere bad. The minors appeared to be in good health, and 83 were subjected to a physical examination, of whom 39 appeared to be in good health and 44 were defective. Of the minors examined practically all were employed in spinning rooms, which were usually well lighted and ventilated, though overheated. The results of the physical examination showed that 14 girls and 11 boys were anæmic, and 7 boys and 5 girls were poorly developed; 2 girls, fifteen and nineteen years of age, had spinal disease; 1 girl, nineteen years of age, was poorly developed and nourished, with valvular heart disease; 1 girl, fifteen years of age, had goiter; 1 boy, fourteen years of age, was deaf in one ear; 1 girl, fourteen years of age, was anæmic, with enlarged tonsils and adenoids; and 1 boy, fourteen years of age, was poorly developed and rachitic. An examination of all the minors fourteen years of age in 1 large establishment showed the following averages: —

	Males.			Females.	
	Weight (Pounds).	Height.		Weight (Pounds.)	Height.
		Feet.	Inches.		Feet.
Good health, ...	96	5	-	98	5
Defective, ...	83	4	8	91	5

Paper Industries. — One thousand and thirty-four minors, employed in papeterie, envelope, blank book and coated-paper factories, were found at work under nearly ideal conditions as regards light, ventilation and other hygienic conditions. Seventy-five female minors operated envelope and other machines, and appeared to be healthy and strong. Twenty-three female minors, one fifteen years and the others seventeen years or over, were employed in the rag sorting rooms, and all appeared to be in good health. All the minors appeared to be in good health except the following: 1 girl, fifteen years of age, had pronounced antero-posterior spinal curvature, but appeared

to be in good health; 1 girl sixteen years of age, and 1 girl eighteen years of age were anæmic; 1 boy eighteen years of age was poorly developed.

Machine Shops and Foundries. — The minors found in machine shops were all robust. No minors were employed in 1 brass foundry but 20 who were employed in another worked under good conditions. Six girls were employed in a large foundry, making small cores. The workroom was large, light, free from dust and provided with modern toilets. The core ovens in this room did not get unduly heated, except in extremely hot weather. Physical examinations were made of 4 minors who did not appear well, with the following results: 1 boy, fifteen years of age, was poorly developed and nourished, weight, 75 pounds; 1 boy seventeen years of age and 1 boy eighteen years of age were poorly developed; 1 boy, eighteen years of age, has been under observation for tuberculosis. These minors were employed in light, clean rooms which were not dusty.

Needle Factory. — Eighty-four minors were employed in a needle factory, many of whom had seen long terms of service there. With the exception of 1 anæmic girl, otherwise in good condition, all appeared well.

Candy Making. — In one large candy factory there were 112 minors, of whom 85 were females and 27 males. Only 1 minor appeared not to be well. A physical examination was made, showing no disease save retarded development. His work was light and did not seem to be more than he should do. The chocolate dipping rooms of the candy factories are cooled during summer by a refrigerating process. The work does not appear to be detrimental to health.

Electrical Work. — Fifty-nine minors were employed in the manufacture of electric light lamps. Although many of the processes required close application, hygienic conditions were found to be excellent. There were said to be very few changes among the employees. Four minors were working in the steam press room of a factory, making electrical insulation. The temperature was high, and there was considerable steam vapor in the room. The management hope to do away entirely with this method of pressing out the forms, so as to avoid the presence of so much steam and heat in the room.

Button Making. — Eighty-four minors were employed in factories making buttons of vegetable ivory. Twelve were found working in a rather dark room, where but little dust was made. Eight operated the machines for sawing the nuts, where large amounts of rather coarse sawdust were created. A high standard of cleanliness, however, was maintained throughout the factory. In a smaller factory 14 young women operated light "cloth-covered tack machines," in a large room where ivory buttons were made, creating but little dust. In a mottling room of a button dyeing establishment 4 young women were subjected to poor ventilation, although several small ventilators were installed, and to much steam in one part of the room and much dust in another part.

Rug Making. — Eleven minors were found working in rug making shops, using old carpets as a basis, 7 as weavers and 4 operating fraying machines.

One factory furnished the minimum of dust and the best of sanitary conditions, while in another very little effort was made to protect the employees.

Laundries. — Thirty-one minors were employed in 8 laundries, in 4 of which the conditions as to light, ventilation and overcrowding were moderately bad.

Rubber Stamp. — Ten minors were employed in a rubber stamp factory, 3 of whom were found at work in a rather dusty vulcanizing room, which, however, was well ventilated.

Fiberloid. — One hundred and thirty-two minors were employed in a large factory making fiberloid or celluloid goods. With 2 exceptions the minors were employed in clean, well-ventilated and well-lighted rooms. Two boys, sixteen and seventeen years of age, were employed in carrying paper into the acid room; 1 was poorly developed and anæmic, and his employers were asked to change his place of work, if possible. In the acid room a mixture of acids is poured upon the tissue paper, and acid fumes are always very strong and sometimes very pronounced.

Office Work. — Two minors working in offices were found to be defective, as follows: 1 young woman, eighteen years of age, was anæmic and of poor appearance; later tuberculosis was discovered. Her work was in an inside office, poorly lighted and ventilated and heated. One young man, nineteen years of age, worked in a well-lighted and ventilated office, and was poorly developed, weight 110 pounds.

Hygiene of Public Buildings and Schoolhouses.

An investigation of the sanitary condition of 68 public buildings was made as follows: 53 schoolhouses; 7 theatres; 2 city halls; 2 railroad stations; 2 almshouses; 1 hospital; 1 police station. Eight out of the 15 public buildings, aside from the schoolhouses, were found to be in a satisfactory condition. Orders were given for changes in the other 7, and these orders were complied with in 5. Of the 53 schoolhouses inspected, 26 were in Holyoke, 8 in Palmer, 5 in Monson, 4 in Granville, and 1 each in Blandford, Brimfield, Holland, Huntington, Montgomery, Russell, Southwick, Tolland, Wales and Westfield.

Cleanliness. — The general cleanliness of all school buildings was good. It was found to be customary to sweep the rooms and halls from two to three times a week, and to follow the sweeping with dusting by feather dusters and cloths. The schoolrooms of most of the buildings were said to be mopped three times a year, except the kindergarten rooms, which in some instances were said to be mopped monthly.

Ventilation. — The ventilation of most of the schoolrooms appeared to be good. There were various systems of ventilation in use, some of which were said to be inoperative. Ventilation was found to be poorer in rooms that were overcrowded with pupils, particularly in the lower grades, where there were from 50 to 60 small children in a room. In 1 school it was alleged that in cold weather if the rooms were well heated they were not well ventilated, but that if the rooms were not well heated the ventilation was good. In

the high school in Palmer the ventilation appeared to be very poor, with inadequate ventilating facilities, which have not been changed, although the scholars have nearly doubled in number since the building was built, twenty years ago. Orders were given to provide further and different ventilating provisions for this school. An appeal was subsequently taken to the local board of health, and after a hearing the board took the matter under advisement, and has not yet rendered a decision. In this same school a room on the third floor was used which was reached by a very steep flight of stairs with one turn on to the second floor. The fire escapes were of wood, consisting of five short flights of stairs with square turns, leading from the rear of the main schoolroom to the ground. The report of improper egresses was submitted to the department of the District Police, in accordance with chapter 389 of the Acts of 1908, by letter.

Sanitaries. — Thirteen school buildings were found with modern, individual water-closets. The sanitaries in the other schools were generally clean, and several different systems were in use, the most common being the Latrine Flush-tank System, which operated unsatisfactorily in some schools. The country schools were provided with earth closets, which were frequently in an unsanitary condition. The sanitaries in 5 schools were in a decidedly unclean condition. Orders were given for changes in the sanitary condition of 16 schools and changes in the ventilation in 2 schools. The Bondsville School in Palmer has installed modern toilet facilities and an improved system of ventilation, and the Notre Dame, Sacred Heart and St. Jerome schools in Holyoke have installed new toilet facilities as a result of these orders.

Tenement Hygiene.

Work on wearing apparel was found to be conducted in 14 tenements and dwellings in Springfield. Licenses were issued in each case.

Matters relating to Water Supply and Sewerage.

Chicopee. — An investigation of the sources of water supply for that part of Chicopee known as Fairview disclosed the fact that in this locality, which was inhabited by about 700 persons, and was without a system of sewerage, wells were the only sources of supply, and many of these were shallow and in close proximity to the vaults.

Ludlow. — The location of a proposed new sewer near Collin's depot in Ludlow was investigated, and the selectmen were instructed to submit the plans to the State Board of Health before constructing this sewer.

Monson. — Investigation of the water supply and sewage disposal of Monson showed that although the town had a public water supply, many houses and establishments were furnished with water from private wells and springs. It was also found that in some mills access could be had to a brook water for drinking purposes. This brook was traced to its source, and it was discovered that the washings from several barns, vaults and farms drained into it. The mill owners were advised by the State Inspector of Health either to discontinue these taps or to label them so that the water would not be

used for drinking purposes. There is no sewerage system in the town, and the sewage is cared for by numerous vaults, cesspools and small private sewers.

Investigation of the water supply for the Hospital for Epileptics in Monson showed that the drinking water was furnished by the town supply, and that water for other domestic purposes came from a small hillside reservoir. The sewage disposal of this institution is maintained in two systems, of which one is for the surface water, which runs off into the fields. The sewage from most of the buildings runs on to a series of eight filter beds for a portion of the year and for the rest of the time on to a large field. The sewage from a small group of buildings runs by a separate system on to the filter beds. The filter beds of both systems appeared to need cleaning.

Palmer. — The village of Palmer has a public water supply, but the villages of Bondsville, Thorndike and Three Rivers depend upon springs and wells for their drinking water. At the time of the outbreak of typhoid fever in Bondsville samples of water were taken from various sources of supply. Later, the supply for Thorndike and Three Rivers was investigated and samples taken for analysis. The results of these analyses by the State Board of Health led them to make certain recommendations to the town of Palmer concerning their use. The water supply at the almshouse was examined and samples of the water taken for analysis. This resulted in recommendations being made by the State Board of Health for the better protection of the water from surface drainage, and changes have been made in accordance with these recommendations. Drinking water for 1 school was taken from a well in the cellar, 3 feet from the privy. This water was examined and found to be unsafe to use.

Springfield. — An examination of four wells used by factories was made, and it was found by the State Board of Health that while three of the well waters were safe to use for drinking purposes, the fourth was polluted, and the factory owning this well was ordered by the State Inspector of Health to discontinue using it.

Westfield. — An inspection was made of the sanitary conditions in connection with the work at the new Springfield water works at Little River. The boarding quarters for the laborers, chiefly Italians and negroes, were found to be in a very good condition regarding cleanliness and general sanitation. Excellent sanitary arrangements were also found for the resident superintendents and engineers.

Appendix.

The following cities and towns were visited and consultations held with representatives of the boards of health: Agawam, Blandford, Brimfield. Chester, Chicopee, East Longmeadow, Granville, Holland, Holyoke, Huntington, Longmeadow, Ludlow, Middlefield, Monson, Montgomery, Palmer, Springfield, Russell, Southwick, Tolland, Wales, Westfield, West Springfield. Wilbraham and Worthington. The 3 cities and the 3 largest towns were found to have boards of health, while in the remaining 20 towns in this district, the selectmen performed the duties of boards of health.

Before releasing diphtheria patients from isolation, Blandford, Holyoke, Palmer and Springfield require two successive negative release cultures; Brimfield, Chicopee, Chester, Hampden, Granville, Montgomery, Worthington, Westfield, West Springfield, Wilbraham and Southwick require one negative release culture. The remaining 11 towns in this district do not require release cultures.

In the matter of the statute requirement for sputum receptacles 13 cities and towns have taken action and the remaining 13 towns have taken no action. The following is the list of the towns that have taken some action, and those marked with a "*" have voted that what is satisfactory to the State Inspector of Health would be approved by them: Chicopee*, Holyoke*, Springfield*, Agawam, Brimfield, Granville, Ludlow*, Monson, Palmer*, Wales*, West Springfield*, Wilbraham* and Worthington.

HEALTH DISTRICT No. 15.

LYMAN A. JONES, M.D., *North Adams, State Inspector of Health.*

This district includes all of Berkshire County.

The work for the year consisted of the investigation of the prevalence of tuberculosis and other diseases dangerous to the public health; the investigation of local nuisances and other matters affecting the public health; the inspection of factories, tenement workrooms, public buildings and schoolhouses; and the examination of minors employed in factories.

Diseases Dangerous to the Public Health.

Tuberculosis. — Letters were sent to 35 physicians in the district urging them to report cases of tuberculosis promptly, and asking them for lists of cases under their care at the time. Seventy-five physicians were interviewed on the subject. In this way, in addition to the names reported to the local board of health, a partial list of all cases of tuberculosis in the district was obtained. The investigation was not completed.

Typhoid Fever. — The district was practically free from typhoid fever during the year. A detailed investigation of 34 cases resulted in the detection of a possible carrier case.

Measles. — During the year there were many cases of measles throughout the district. The disease was epidemic in North Adams and Williamstown, and to a less extent in Pittsfield and Stockbridge. One hundred and seventy-two cases in North Adams were investigated and reported to the State Board of Health.

Scarlet Fever. — Except in Pittsfield and Great Barrington, where scarlet fever was somewhat prevalent in the spring, cases of this disease were few and scattering.

Diphtheria. — Cases of diphtheria were also infrequent throughout the district, except in Adams, where some cases were reported from time to time.

Smallpox. — There was no case of smallpox in the district during the year. Recently a case of smallpox was reported as existing in New York State,

not far from Egremont and Great Barrington. The health authorities and physicians in these towns were visited, and plans were made to meet any emergency that might arise.

Local Nuisances.

Four local nuisances were investigated and the attention of the local health authorities called to the existing conditions. The two nuisances caused by faulty sewage were remedied.

Factory Hygiene.

During the year 156 visits were made to factories: 82 first visits, 44 second visits, 14 third visits, and 16 fourth visits. Sixteen visits were also made to mercantile establishments. Written communications were sent to manufacturers calling their attention to 67 objectionable conditions existing on their premises, with the request that they be remedied. Thirty objectionable conditions were pointed out orally. Ninety of these objectionable conditions were done away with. As regards light, ventilation, dust, cleanliness, etc., efforts were made to improve conditions that were manifestly deficient. It was found in general that employers could be persuaded to make any changes when the reason for so doing was made clear to them.

In 16 factories new water-closets were installed, and in 26 factories the closets were much improved by repairing the plumbing and floors, and by painting and whitewashing. Light was markedly improved in 6 establishments; ventilation in 3; the removal of dust was better provided for in 3; and a higher degree of cleanliness was maintained in 4.

Seventeen of 20 orders to provide sputum receptacles, and 8 of 22 orders to provide first-aid outfits, were complied with.

It was found difficult to establish an exact classification and grading of the various establishments visited. One mill, for instance, might be excellent in all its appointments except that the water-closets were neglected; another mill might be admirable in every respect except that in one department the lighting was poor, or the ventilation inadequate. Such conditions, however, would prevent designating these particular establishments among the best.

Hygiene of Mercantile Establishments.

Thirteen hotel and restaurant kitchens were inspected. In 9 instances suggestions were made in writing that the kitchens should receive a fresh coat of paint or kalsomine. In consequence, 5 kitchens were improved. One kitchen, where the walls were papered, was repapered and the walls painted. A hotel bakeshop, where the walls and ceilings were black with smoke, was thoroughly renovated. Another hotel kitchen and 2 restaurant kitchens were painted throughout. The remaining 4 have not been reinspected.

Health of Minors in Factories.

During the year 1,456 minors were seen and questioned in 49 different establishments. In 40 cases physical examinations were made, 30 because of tubercular family history, and in 1 case the minor was visited at his

home. In 37 of the factories visited the conditions under which the minors were employed were satisfactory as to lighting, ventilation and cleanliness; and in no establishment was a minor found exposed to dangerous processes or to probable unhygienic influences. In 2 cracker bakeries those employed in attending the cracker machines and ovens were exposed to considerable heat. Excessive heat was also noticeable in a clothing factory, where 6 minors were employed at pressing. In cold weather, when the windows are closed, the ventilation is probably inadequate. The health of minors employed appears to be good. No case of pulmonary tuberculosis was found. A few minors, while showing no signs of disease, appeared less vigorous, and were noted for further observation. One case of tuberculous hip disease of long standing was observed in a minor seventeen years old. He was employed as a spinner in a cotton mill. The parents were notified that the boy's condition was such that he ought not to work in the mill. Notwithstanding the advice given the boy continues at his work. Were he to be discharged the other members of the family employed in the mill would undoubtedly leave. Many of the minors appeared undersized. This was noticed particularly in the cotton mills among minors of foreign parentage. In 2 factories all the minors between the ages of fourteen and sixteen, about 150, were made the subject of special study. No conclusions, however, have as yet been reached.

The following notes indicate in a general way the hygienic conditions found to exist in various industries: —

Industrial Hygiene. The Relation of Industries, Processes or Unhygienic Conditions to Health.

Paper Mills. — Paper mills in this district manufacture chiefly the finer grades of writing and tissue papers. Most of the mills are modern and well appointed, with large cutting and large dusting rooms separated. The latter rooms are generally provided with a suction apparatus to remove the dust. In 2 of the older mills, especially where less clean stock is used, and where the large cutting room is not separated from the large dusting room, the employees are exposed to an undue amount of dust at times, even though fans are in use. Some of the older mills lacked suitable closets. Now, however, with but one possible exception, all are provided with excellent or reasonably good accommodations. One large stationery manufacturing plant, where many minors are employed, is excellent throughout.

Cotton Mills. — Under this heading are included the establishments for the manufacture of cotton cloth, ginghams, cotton spreads and cotton warp. With the exception of a few smaller establishments, and some of the older buildings of wood or stone, the cotton interests of the district are carried on in buildings of modern construction, where satisfactory provisions exist as to lighting and ventilation. The carding processes give rise to a considerable quantity of dust, and no satisfactory measures have yet been devised to remove it. The standard of cleanliness was found to vary from good to excellent. In the majority of the mills the water-closets were good, but in 3 mills

they were distinctly bad. The closets in these mills, however, have been replaced by new closets or new plumbing. In 3 other mills where the closets were bad, renovating, painting and added attention have resulted in satisfactory conditions.

Woolen Mills. — Most of the mill buildings are old, except for some modern additions, such as a weave room, a dyehouse, etc. In consequence, the standard of sanitation in this industry is not so high as in the others. Objectionable conditions were frequently found as to the condition of the closets. Many of them were moderately or distinctly bad. In every instance these conditions were remedied to a greater or less extent. Owing to the nature of the stock used in the manufacture, the floors, walls and ceilings are dark and stained, with the result that the workrooms are poorly lighted and ventilated. In instances where new construction has been undertaken the standard in all respects is much higher and entirely satisfactory. One mill, until recently without any care or attention as to sanitary conditions, is so old and unsatisfactory that it is doubtful if anything save the erection of a new building will make conditions as they should be.

Shoe and Leather Factories. — These factories are well lighted, as a rule, and the ventilation is reasonably satisfactory for the most part. The water-closet accommodations are not as good as they should be. In 2 instances the closet is in the middle of the workroom and ventilates into it. The condition of these closets indicate that they have received far too little attention. While the location of the closets remains unchanged, in other respects marked improvement has been made by means of cleaning, painting or whitewashing.

Machine Shops. — With 1 exception the plants where work of this sort is carried on are in excellent condition in every respect. In 1 plant an entirely new wash and toilet room, with hot and cold water, shower baths, closets, etc., has been installed. Another large plant, where electrical machinery is made, is housed in new and modern buildings, which afford an abundance of light and air. The conditions throughout are excellent.

Tenement Hygiene.

The only work in the district done in dwelling houses consists of the turning of collars and cuffs. Twenty tenements were inspected and 16 licenses issued. Almost without exception the homes were of the better class, where the work was done in good surroundings, and was carried on in order to obtain a little extra spending money.

Schoolhouse Hygiene.

Fifty-four school buildings were inspected in the following towns and cities: —

Adams,	7	Lee,	4
Becket,	1	Great Barrington,	4
Cheshire,	1	North Adams,	9
Clarksburg,	2	Pittsfield,	12
Dalton,	4	Sheffield,	3
Hinsdale,	1	Williamstown,	6

In 3 schools the privies were in bad condition. In 1 instance the conditions were such that the two women teachers were not decently provided for. In all cases the objectionable conditions were promptly remedied. In 1 school dark closets were lighted by electricity. One school was found located in a portion of a factory building, the rooms in which were damp and poorly ventilated. This matter was brought to the attention of the chairman of the local board of health.

Matters relating to Water Supply and Sewerage.

Until the present year in the town of Adams sewers were built, here and there, to accommodate this or that locality, according to the exigencies of the case, without any reference to plan or system that would eventually provide for the whole town. At the instigation of the engineering department the State Inspector of Health brought to the attention of the town officials and to some of the leading citizens the desirability for a proper sewer survey, which would furnish plans in accordance with which the work done on sewers from year to year would ultimately meet the needs of the whole town. As a result, an article making an appropriation for such a survey was inserted in the town warrant, and at the annual meeting of the town the money was voted. The survey and the plans are now approaching completion. While North Adams, for the most part, has a very satisfactory and reasonably complete sewer system, nothing has yet been done looking toward the removal of the sewage from the Hoosac River, a matter that has been urgent for some time. At present the subject is being brought to the attention of prominent citizens with the idea of attempting to secure in another year an appropriation to be used in obtaining expert advice as to the manner and plans which may be employed for the disposal of the city's sewage.

NUMERICAL DATA.

Schedule of Work done in District No. 15.

Towns visited one or more times,	15
Local nuisances investigated,	4
Prevalence of tuberculosis and other diseases dangerous to the public health: —	
Physicians notified about tuberculosis,	35
Physicians interviewed about tuberculosis,	76
Lists of deaths from tuberculosis obtained from towns,	9
Cases of disease dangerous to the public health investigated: —	
Tuberculosis,	3
Typhoid fever,	34
Measles,	172
Smallpox,	1
Suspected typhus,	1
Concerning the health of minors employed in factories: —	
Factories visited where minors worked,	42
Minors inspected and interviewed,	1,456
Minors examined,	40
Home of minor visited,	1

Sanitation of factories, tenements where clothing is made, and public buildings: —		
Industrial establishments inspected,		156
First inspection,	82	
Second inspection,	44	
Third inspection,	14	
Fourth inspection,	6	
Mercantile establishments inspected,		34
First inspection,	27	
Second inspection,	7	
Requests for improvement,		106
Results of requests: —		
Complied with,	89	
Not yet ascertained,	16	
Establishment closed,	1	
Tenements inspected where work on clothing is done,		20
Licenses issued for such work,		16
Schoolhouses inspected,		54
Questions relating to water supply, drainage and sewerage: —		
Water supplies visited,		5
Public,	4	
Private,	1	
Sewage-disposal plant visited,		1
Interviews on Adams sewerage survey,		17
Interviews on North Adams sewage disposal,		27

REPORT UPON THE INVESTIGATION OF LOCAL OUTBREAKS OF INFECTIVE DISEASES.[1]

Following are accounts of local outbreaks of disease investigated by agents of the Board: —

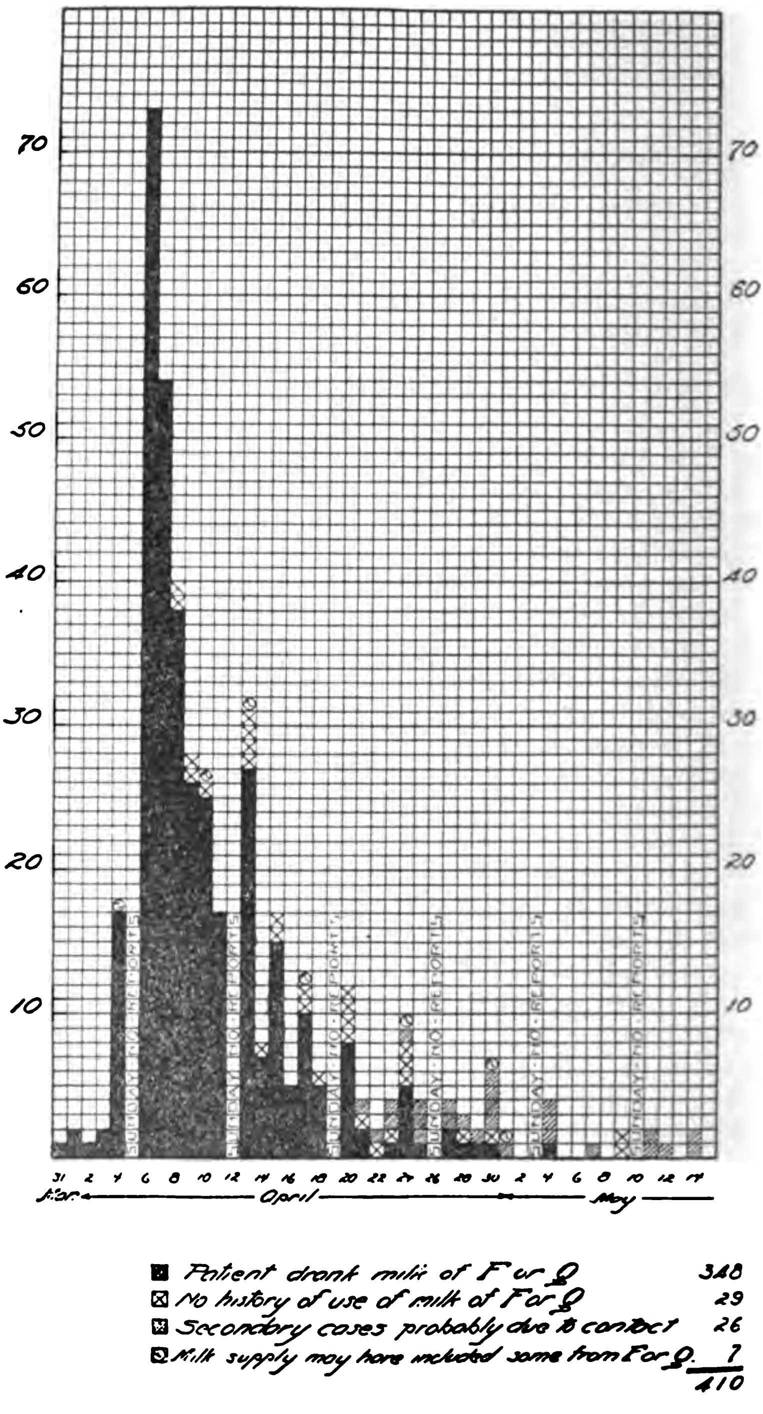
AN UNUSUALLY EXTENSIVE MILK-BORNE OUTBREAK OF TYPHOID FEVER IN JAMAICA PLAIN.[2]

On March 31, 1908, after several months of practical freedom from typhoid fever, a case of that disease occurred in Jamaica Plain, followed on April 1 by 2 more, on April 2 by 1, and on April 3 by 2. On April 4 inquiry was made as to the possibility of a common cause, and it was learned that more cases were being reported. The number reported for that day proved to be 17. On Monday, April 6, the number reported was 73 (which number includes the cases of two days, there being no mail delivery on Sunday), and during the next five days the numbers reported were, respectively, 54, 38, 26, 25 and 17. From Monday, April 13, to Saturday, April 18, inclusive, the numbers reported were, respectively, 32 (Sunday and Monday), 7, 17, 5, 13 and 5. During the next week the numbers were, respectively, 12 (Sunday and Monday), 4, 2, 4, 10 and 4. Between Monday, April 27, and May 15 the total number of cases reported was 30, a majority of which (18) were undoubtedly contact cases. There were thus reported during this period of about six weeks no fewer than 410 cases of typhoid fever, in which total are not included the cases of 2 persons who came into the district already ill and a number which in the excitement naturally caused were wrongly diagnosed as typhoid.

So sudden an explosion, occurring in a district hitherto practically free from the disease, suggested, before it had reached its height, the probability of a common milk supply. It was learned on April 5 that 23 of the 24 cases already reported were on the routes of two milkmen. The 73 cases reported on April 6, the 54 reported on April 7, all but 6 of the rest of the cases reported during that week, and all but 12 of the cases reported during the second week were also on the same milk routes.

[1] Accounts of investigations of small outbreaks of infective diseases may be found in the report of the work of the State Inspectors of Health.

[2] Reported in "Monthly Bulletin," May, 1908.


70
60
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10
SUNDAY - NO - REPORTS
31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 2 4 6 8 10 12 14
Mar. April May
Patient drank milk of F or G 348
No history of use of milk of F or G 29
Secondary cases probably due to contact 26
Milk supply may have included some from F or G. 7
410

Of the 410 cases reported, 348 primary and 23 secondary cases proved to be in families supplied by these two men, who hereafter will be designated as F and Q. Since the number of cases occurring on each route was about the same (primary, 175 and 173; secondary, 6 and 17, respectively), and for reasons which will presently appear, the two supplies are presented as one in the accompanying chart, which illustrates the characteristically explosive nature of a milk-borne outbreak. There were 29 cases in which no history of the use of their milk could be obtained, and 7 in which there was a possibility that the victims had on some one or another day drunk it. Those 36 persons were among the regular customers of no fewer than 15 different milkmen. More than half of them were adults, who, in going about freely and perhaps lunching and dining in restaurants and in the homes of their friends, may have consumed some of the same milk, or may have ingested the infection with some other article of food; and all but 3 of the remainder were children of school age, who also doubtless visited about to some extent.

Age Periods. — The persons seized in this outbreak were distributed according to age as follows: —

1 to 5 years,	77
6 to 10 years,	75
11 to 15 years,	49
16 to 20 years,	42
21 to 25 years,	44
26 to 30 years,	34
31 to 35 years,	24
36 to 40 years,	25
41 to 45 years,	15
46 to 50 years,	9
Above 50 years,	16
Age not stated,	3
	410

Number of Households invaded. — The 410 cases were distributed as follows: —

Single cases in 216 households divided as to milk supply as follows: —

F,	97
Q,	86
All other milkmen,	[1] 33
	216

[1] Including 1 contact.

In 79 households multiple cases occurred as follows: —

2 cases,	57 households,	total, 114;	contacts, 12
3 cases,	12 households,	total, 36;	contacts, 7
4 cases,	7 households,	total, 28;	contacts, 5
5 cases,	2 households,	total, 10;	contact, 1
6 cases,	1 household,	total, 6;	–
	79	194	25

Of the total number of contact cases (26), 23 occurred in households supplied by F and Q.

The Milk Supply of F and Q. — In common with eight other milkmen, Messrs. F and Q obtained their supply from the car of a contractor who derived this particular carload from eight towns, in none of which had a case of typhoid fever occurred during the previous three months, excepting that of an Italian laborer in no way connected with milk production. Each milkman who went to this car received milk from the same dairies regularly, and the fact that there was but one dairy whose product was given to both F and Q was naturally suggestive that the infective material came to Jamaica Plain from this particular dairy. Inquiry at the place of production revealed that not only was there no history there of any sickness whatever, but also the interesting fact that the owner was marketing about 60 cans a day, only 40 of which were sent to Jamaica Plain, 20 being sold daily to a dealer in another place, where there had been but one case of typhoid fever, and that one not on his route. It was evident, therefore that the infection did not come from the premises of this producer.

Among the first victims of the disease to be reported was the milkman F himself (April 4). It appears that on or about March 20 F consulted his family physician, who concluded that F was merely tired and overworked. From that time until April 2 F felt ill, but was able to attend to his daily work, which included the general handling of his milk. On April 1 he consulted his physician again, and at that time his temperature was 100°, and he was suffering with diarrhœa. On April 2 a diagnosis of typhoid fever was made, and he took to his bed. On April 10 he died, and the autopsy performed by Dr. George B. Magrath revealed, among other lesions, an ulcer, 1.5 by 2 centimeters, at a point about 60 centimeters below the ileocæcal valve, which ulcer, being of not less than three weeks' development, indicates that F must have been suffering from typhoid fever as early as March 20. Other lesions observed in the intestines — numerous ulcers of varying size — were of more recent origin, and represented, according to Dr. Magrath, the conditions found toward the end of the second week.

Considering that F had been ailing for a period of about two weeks before he took to his bed, but not to such an extent as to prevent him from handling the milk, it is not difficult to surmise in what manner the supply became contaminated with the exciting cause of the disease, for the hands of the average milkman do not receive the same degree of care as those of an operating surgeon, and with more or less frequent occasion for interrupting the work of handling the milk in order to respond to natural calls, specific contamination, first of the fingers and then of the milk, is very likely to occur.

With the supply of Q, however, the connection is by no means clear. It was reported that Q received from the dairy which they had in common only those cans which F left for him, after tasting all and selecting those which he wished for his own trade. This, however, is denied on apparently good authority, and, instead, it is said that on only two occasions, namely, March 15 and March 18, did F precede Q at the car. It is further stated that although each can was tasted before acceptance, those that were rejected were set aside and not delivered to Q. However this may be, and whether or not F had an opportunity to infect the milk of Q on either of these two days or on any subsequent day, it is certain that there was the greatest possibility of an interchange of cans between F and Q, for it was the custom of each to return the cans to the car washed, but by no means sterilized; and after they were filled at the dairy and returned, Q was as likely as F to receive cans which had been supplied to and handled and returned by F. Certain it is that the first infection did not occur at the place of production and was not due to the fault of the farmer; and equally certain is it that F, during two weeks of ambulant typhoid fever, had ample opportunity to infect his supply and to reinfect it again and again, and to spread the infection to Q's supply through the nonsterilized cans of the contractor, which they used in common.

An Outbreak of Typhoid Fever in Newburyport.[1]

On August 10 it came to the knowledge of the State Inspector of Health of District No. 8 that typhoid fever existed in Newburyport, and a careful investigation was made on that day, which disclosed the fact that 9 persons were seized previous to August 10 and that 3 persons had been stricken in July, making a total of 12 who had come down with the disease. During the course of the outbreak all possible information concerning the prevalence of the disease was obtained. It was learned that of 38 cases which were reported to the State Board of Health between July 18 and October 31, inclusive, 27 occurred during

[1] Reported in "Monthly Bulletin," October, 1908.

the month of August, — 9 during the week ending August 8 and 10 during the week ending August 15, making 19, or 50 per cent, of the total number occurring between August 1 and 15, inclusive. But 4 cases occurred during September and 5 during October, which were, in all probability, secondary cases, the last case being reported on October 23. It will, therefore, be seen that the outbreak was explosive in character, and that the greatest number of cases occurred during the first two weeks in August.

Careful study of the facts gained by investigation failed to show the public water supply to be a means for the spread of infection. While the cases of the disease were widely distributed throughout the city, a considerable number of them were localized, and neither in numbers nor in thoroughness of distribution did the outbreak coincide with an epidemic from water-borne contagion.

Likewise, an investigation of the ice supply failed to disclose any facts proving this to be a means whereby the contagion was spread.

While it is true that about 50 per cent. of the persons afflicted may have received milk, directly or indirectly, from one dealer's supply, no source of infection on this dealer's premises, or among his employees, could be found. Moreover, further investigation disclosed the fact that on none of the 40, or more, farms where milk was produced for 17 dealers, who supplied milk at the homes of the persons afflicted, could be found a source of infection which might account for the outbreak.

In this outbreak, upon the evidence of the facts at hand, therefore, the cause of the infection could not be determined.

The accompanying chart gives the incidence of the disease by week endings.

The Occurrence of Infantile Paralysis in Massachusetts in 1908. (Second Paper.[1])

In pursuance of the policy inaugurated in 1907, the State Board of Health in 1908 continued the investigation into the occurrence and distribution of cases of infantile paralysis in the State of Massachusetts, with especial reference to etiology. As in the previous year, circulars were sent to all physicians asking them to report to the Board cases coming under their observation, and to physicians reporting cases blanks were sent to be filled out. From these blanks the following data were obtained.

Physicians seeing such cases were also requested to forward to Dr.

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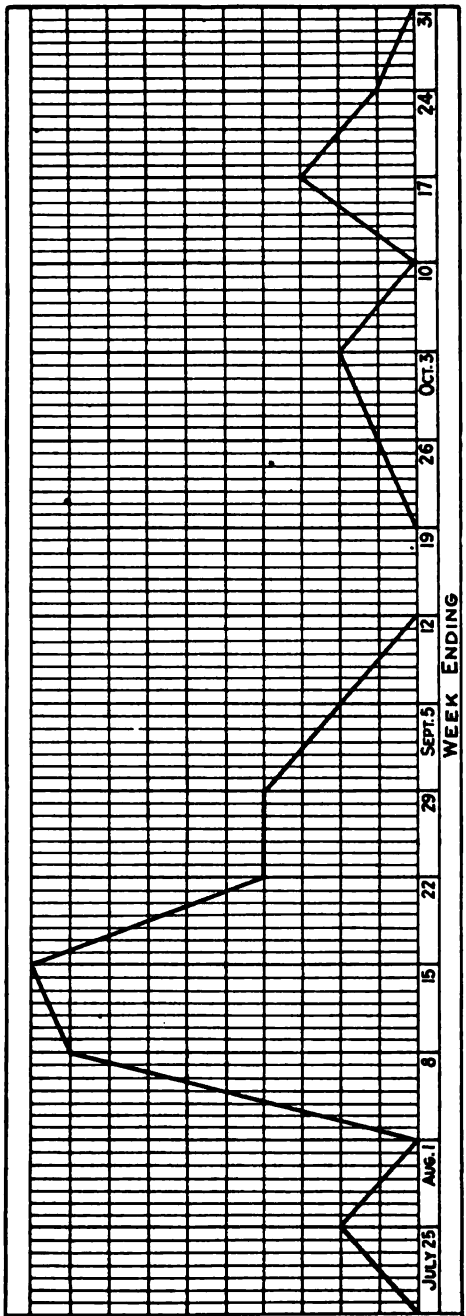
[1] By Robert W. Lovett, M.D., Boston. This article first appeared in the "Boston Medical and Surgical Journal" for July 22, 1909. The apparent discrepancy in dates is due to the fact that this article appeared in advance of the publication of the report of the State Board of Health for 1908.



WEEKLY INCIDENCE OF TYPHOID CASES IN NEWBURYPORT

Theobald Smith, pathologist of the Board, fresh specimens of stools from acute cases for bacteriological study, with reference, of course, to etiology. It is not possible as yet to state the results of these examinations.

The present paper will first present a brief abstract of the literature dealing with the epidemiology of the affection appearing since the last report ("Boston Medical and Surgical Journal," July 30, 1908), and, second, an account of the features of the disease as occurring in the State in 1908. The serious epidemic which occurred in 1908 in Franklin County will be dealt with separately by Dr. H. C. Emerson, who investigated it on behalf of the Board.

Abstract of Important Literature.

Bacteriology and Experimental Production. — The most valuable contribution of the year toward our knowledge of the disease has been made by Landsteiner and Popper of Vienna,[1] who have apparently succeeded in producing the disease in monkeys by inoculation. A boy of eight died of the disease on the fourth day. The autopsy showed typical anterior poliomyelitis. In the spinal cord and cerebro-spinal fluid there were no organisms to be found and cultures were sterile. Parts of the spinal cord were then emulsified in salt solution and injected into the abdominal cavity of rabbits, guinea pigs, mice and two monkeys. In the first three named no paralysis ensued and the spinal cords were normal.

The first monkey became violently ill on the sixth day and died on the eighth. He lay on the floor of his cage and his power to move his limbs was not investigated. After death changes typical of anterior poliomyelitis were found.

The second monkey was noted to have lost all power in the hind legs on the seventeenth day. No paralysis was present on the twelfth, although it may have been present before the seventeenth in some degree. He was killed on the nineteenth day, and again typical pathological changes were found in the central nervous system.

From the spinal cord of this monkey inoculations were made into two other monkeys, with negative results.

The conclusion of these authors is that "a so-called invisible virus, that is, one belonging to the class of the protozoa, is the cause of the disease."

With regard to the affection of domestic animals in epidemics of infantile paralysis, this was alluded to in the Rutland epidemic, reported

[1] Zeitschrift für Immunitätsforschung und experimentelle Therapie, 1909, Bd. II. heft 4, teil 1.

by Caverly[1] in 1894 (horses and poultry). Dana investigated a hen with paralysis and found the bacteriology negative, and the changes in the cord "acute infectious softening rather than myelitis."[2] It was noted by Wickman that in the Swedish epidemic of 1905 dogs were apparently affected in many instances with the children, but he was not convinced of the identity of the two affections.[3] Free reported that pigs and chickens were affected in the Michigan epidemic, alluded to below. The attention of the State Board of Massachusetts has been called to the occurrence of infantile paralysis in a mother and daughter shortly after an epidemic of "leg weakness" in the chickens of the household, and the matter is under investigation.

Pasteur,[4] Foullerton and MacCormac investigated the cerebro-spinal fluid of a case of poliomyelitis, finding in it mononuclear round cells. On staining, large cocci grouped in pairs and tetrads were found eleven days and four weeks after the onset of the disease. Cultures were negative. Nine rabbits were inoculated with the fluid, of which some were paralyzed after about six weeks and the cord and spinal fluid of one of these was again inoculated into other rabbits, with positive results. The inoculation from this series was negative.

Cocci which did not grow were found in the spinal fluid of affected animals, but in the one cord examined there were no changes in the ganglion cells or about the vessels. The conclusion of these authors, that anterior poliomyelitis is not the result of a specific cause, is disputed by others on the ground that the experimental paralysis is not anterior poliomyelitis (Wickman, Landsteiner and Popper).

Epidemics recently reported.

In Salem,[5] Va., and vicinity occurred between June 2 and Aug. 10, 1908, 25 cases; the neighboring city of Roanoke, seven miles distant, in close communication with Salem, escaped with 1 case. The cases all occurred in children under six, the youngest being thirteen months old. The death-rate was 12 per cent.

In September, 1908, there occurred "a number of cases" in and about Whittemore, Ia.[6] The following regulation was passed by the State Board of Health of Iowa: "It is hereby ordered by the State Board of Health that all physicians and osteopaths practicing in Iowa shall

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1 Wickman: Beitr. z. Kenntniss der Heine-Medinischen krankh. Berl., 1907.
2 N. Y. Med. Rec., Dec. 1, 1894.
3 Boston Med. and Surg. Jour., 1895, III., p. 14.
4 Lancet, 1908, vol. I., 484.
5 Wiley and Darden: Jour. Am. Med. Asso., Feb. 20, 1909, p. 617.
6 Iowa Health Bull., November, 1908, xxii., No. 5.

promptly report to the mayor or township clerk all cases of poliomyelitis occurring in their district," etc.

In central Wisconsin,[1] in the summer of 1908, there occurred an epidemic, with 60 cases in one of the smaller cities and 14 deaths.

In central Pennsylvania the disease was active in the summer of 1907,[2] 100 cases having been seen in and about Dubois, and Sinkler[3] estimated that in Philadelphia 30 per cent. more cases than usual were seen in that summer. Sinkler elsewhere[4] speaks of the etiology as follows: "The nature and progress of the disease indicate clearly that it is due to an infection. It is obvious, therefore, that the micro-organism which produces the infection is one which is developed by hot weather. A large proportion of cases have some form of intestinal trouble. . . . It is probable, therefore, that the micro-organism producing the disease has found its entrance into the system through the intestinal tract and thence to the spinal cord."

McCombs[5] contributed a study from the Philadelphia Children's Hospital of the disease as observed at that institution between 1903 and 1907, showing 50 per cent. more cases occurring in the summer of 1907 than the sum of all cases for the preceding four years. Forty-three cases in all were analyzed.

Manwaring[6] reported an epidemic of 30 cases in Flint, Mich., occurring in the summer of 1908, and alluded to[7] other epidemics in the State, one in western Michigan, reported by Ostrander, and another in Chesaning.

In the Flint epidemic the average age of affected cases was ten years. Of cases under ten all lived, between ten and twenty the mortality was 25 per cent., over twenty the rate was 75 per cent., corresponding to Wickman's observations.

Griffin[8] described an epidemic of 20 cases in Oceana County, Mich., occurring between July and September, 1907.

Twenty-nine cases were reported by Clowe[9] as having occurred in Schenectady in the summer of 1907. There were 2 deaths in adults and 10 of the cases were seriously sick; 5 were classed as having made a complete recovery; 19 cases were less than four years old.

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1 Informal communication from Wisconsin State Board of Health.

2 Free: Jour. Nerv. and Ment. Dis., April, 1908, p. 259.

3 Sinkler: *Ibid.*, p. 260.

4 Arch. of Diagnosis, January, 1908, p. 31.

5 Arch. of Pediatrics, January, 1908, p. 36.

6 Jour. Mich. State Med. Soc., April, 1909.

7 *Ibid.*, February, 1908.

8 Wickman: Studien über Poliom. Acuta, Berlin, 1905.

9 Albany Med. Jour., 1908, XXIX., p. 799.

Partial reports[1] of the New York epidemic of 1907 have already appeared in various articles. It seems best to wait for the published reports of the committee appointed to investigate the epidemic before analyzing the conclusions reached.

In and about Vienna, in the summer of 1908, between the end of July and October, there occurred many cases of infantile paralysis, more, according to Zappert,[2] than had been seen since 1895. He notes the large proportion of older children to be affected, and speaks of it as a frequent occurrence in large epidemics.

An epidemic occurred in Victoria,[3] Australia, in their autumn of 1908, selecting the months of March to June. It occurred chiefly in the most densely populated suburbs of Melbourne. There were 6 deaths in 135 cases recorded, and the bacteriological findings are not sufficiently clearly given in the abstract, which alone is available, to be commented on.

Byron Bramwell[4] presented an analysis of 76 cases observed by him, reaching over a period of years.

One of two inferences is possible from the literature of the last year or so: either the disease is increasing rapidly in this country, or the attention of the medical profession has been called to the disease and more cases and epidemics have been recognized and reported.

Cases reported in Massachusetts.

Occurrence and Distribution. — As against 234 cases of infantile paralysis reported in 1907 only 136 cases were reported in 1908. It is interesting to note in this connection that, in 1907, 444 cases of cerebrospinal meningitis were reported, while in 1908 there were only 183 cases. It was noted in the previous report that the two diseases, however, reached their maximum at different seasons.

In 1907 the cases of infantile paralysis in their distribution in a general way corresponded to the density of population in the State, grouping themselves as a rule about the centers of densest population, and only in and about Pittsfield, where some 28 cases occurred, was there evidence of any marked epidemic. (See map for 1907, following p. 764.)

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[1] H. W. Berg: N. Y. Med. Rec., 1908, LXXIII., p. 1; Joseph Collins: *Ibid.*, 1907, LXXII., p. 725; Terriberry: *Ibid.*, 1907, LXXII., p. 920; Jennings: Med. Rev. of Reviews, May, 1908, p. 197; Collins and Romeiser: Jour. Am. Med. Asso., May 30, 1908, p. 1766; Starr: *Ibid.*, July 11, 1908, p. 112 (with list of epidemics); V. P. Gibney and C. Wallace: *Ibid.*, Dec. 21, 1907, p. 2082.

[2] Wien. med. Wochenschr., 1908, XLVII., 2563.

[3] H. D. Stephen: Intercol. Med. Jour. of Australasia, November, 1908; Abst. Lancet, April 3, 1909, p. 999.

[4] Scot. Med. and Surg. Jour., June, 1908, p 501.

In 1908, however, the grouping of cases was largely different, and bore slight relation to the density of population, and, as a rule, where the disease was prevalent in 1907 it was rare in 1908, thus corresponding to the conclusions reached by Scandinavian investigators, that regions severely affected one year were for a while comparatively immune. As against 28 cases in the western end of the State in 1907 there were only 3 in 1908. In and about Lowell, Fall River and Haverhill there were in 1908, as in 1907, apparent slight centers of infection.

About half (69) of the cases reported in the State occurred in Franklin County, the remainder (67) being distributed through the State.

Cerebro-spinal meningitis, however, in the year 1908 showed practically the same distribution as in 1907, in general being grouped about the densest population. These comparisons are made because cerebrospinal meningitis is an infectious disease, apparently mildly contagious,[1] affecting many children, and manifested in the central nervous system. Presenting these points of similarity it has been thought that its characteristics might possibly in the future throw some light on the disease under consideration.

For purposes of simplicity the epidemic in Franklin County will be dealt with separately by Dr. Emerson, and in the following analysis will be considered *only* the cases occurring in the State at large. The two analyses taken together will give the occurrence of the disease in the whole State.

The *distribution* of the 67 cases may be seen in the map for 1908, accompanying this paper.

Contagion has been so carefully studied in the epidemic that it will not be dwelt on here.

Traumatism. — In 1 case a history of exposure to dampness was given, and in 9 cases histories of trauma preceding the disease. These histories, however, were in many instances vague and unreliable.

Season of Onset. — Cases occurred as follows: January, 1; February, 1; March, 1; May, 2; June, 1; July, 9; August, 11; September, 14; October, 15; November, 7; date not given, 5.

The season of onset does not differ materially from that in 1907, but does differ essentially from the season of onset in Franklin County, where it was as follows: March, 1; April, 1; June, 6; July, 28; August, 26; September, 5; November, 2.

Age. — The largest number of cases (19) occurred between the ages of one and two, and for the years from two to eight there were reported from 3 to 8 cases for each age; after this the reported cases were 1 or

[1] Edler and Huntoon: Jour. of Med. Research, June, 1909.

2 a year up to 16. There were 2 adult cases reported, one twenty-one and one forty.

Sex. — There were 39 males, 26 females and 2 not stated.

As to other factors of possible interest in the etiology, 38 lived in detached houses and 27 in tenements, while 2 were not stated. Of the cases in tenements, 12 of the patients lived on the first floor, 10 on the second, 4 on the third and 1 in the basement. Sanitary conditions were described as excellent in 24, good in 20, fair in 16, bad in 5.

Symptoms. — In 54 cases fever was present, the temperature ranging from 100 to 104. In 1 case no fever was present. In 12 cases no record given. Brain symptoms occurred in 15 cases. There was usually delirium during the febrile state. Vomiting is recorded in 21 cases, constipation in 20 and diarrhœa in 8. Retraction of the head present in 10 cases. Pain is recorded in 46 cases, absent in 2. The pain was usually along the distribution of the paralysis, and did not, as a rule, subside at once after the acute attack. Incontinence of urine and feces in 2 cases, incontinence of urine in 1, retention and later incontinence of urine in 1.

Relation of Beginning of Paralysis to Onset of Fever.

Paralysis preceded the attack by two days,	1
Occurred on the same day,	5
On the next day,	6
Two days later,	11
Three days later,	13
Four days later,	8
Five days later,	4
Six days later,	1
Seven days later,	3
Eight days later,	1
Ten days later,	2
Two weeks later,	1

Complete recovery is said to have occurred as follows: —

Five days from beginning of disease,	1
Ten days from beginning of disease,	1
Two weeks from beginning of disease,	3
Six weeks from beginning of disease,	1
Three months from beginning of disease,	1

Distribution of Paralysis.

One leg,	
Both legs,	
One arm,	
One arm and one leg,	
One arm and both legs,	
Both arms and one leg,	
Four extremities,	
Not stated,	

Mortality. — Four cases terminated fatally, 2 dying of r paralysis and 2 of exhaustion, stupor and convulsions.

Conclusions.

The conclusions which would seem warranted by the investi 1908 are as follows: —

That the disease was less prevalent in the State than in 190 also cerebro-spinal meningitis.

That the distribution of cases was unlike that of 1907, affected seriously in 1907 largely escaping in 1908. That thi the opposite of the almost identical distribution of cerebro-spin gitis in the same two years.

That half of the cases occurring in the State were compris epidemic in Franklin County.

Finally, it may be stated that it is not to be expected that any light will be thrown on the etiology of the disease by its ob during any one year, but it is hoped that by a study of the di a period of years in the same territory, conclusions of value established. It is also to be hoped that by the study of the fresh cases some light may be thrown on the etiology.

An Epidemic of Infantile Paralysis in Western Massac in 1908.[1]

[Note: — The following investigation of this epidemic was made at gestion of Dr. Henry P. Walcott, chairman of the State Board of Heal information was obtained through the courtesy and assistance of the pl

[1] By Herbert C. Emerson, M.D., Springfield, State Inspector of Health, District 14. A of this article first appeared in the "Boston Medical and Surgical Journal" for July 22, apparent discrepancy in dates is due to the fact that this article appeared in advance o lication of the report of the State Board of Health for 1908.

which enabled the writer to visit the homes of all the cases reported in this epidemic. The writer spent a month living in the towns in which the epidemic occurred, and made several subsequent visits to these places.]

Sixty-nine cases of infantile paralysis, or approximately one-half the total number reported in the State during 1908, occurred in western Massachusetts, and were distributed as follows: —

Colrain,	24	Erving,	2
Buckland,	9	Adams,	1
Shelburne Falls,	8	Cheshire,	1
Montague,	7	Deerfield,	1
Bernardston,	5	Gill,	1
Greenfield,	4	North Adams,	1
Heath,	4	West Hawley,	1

Geographical Distribution.

Three isolated cases occurred in the extreme northwestern part of the State in three contiguous towns, viz., Cheshire (August 7), Adams (August 16), North Adams (November 3). The remaining 66 were distributed throughout a group of eleven neighboring towns in the western part of the State, south of the Vermont State line. The territory involved is a sparsely settled hill country, with numerous streams furnishing water power for various manufacturing interests. The communities are largely agricultural, with a considerable factory population in the larger towns. Most of the cases occurred in the valley of the Deerfield River (Shelburne Falls-Buckland) and that of its main feeder the North River (Colrain), and at that point on the Connecticut River (Turners Falls), where the Millers and Falls rivers empty into it. As both the valleys of the Deerfield and North rivers are very narrow the bulk of the population lives naturally very near these streams.

Twenty-four cases occurred in Colrain (population 1,800), a town of five villages, containing three cotton mills, in the narrow North River valley. Nine of these cases occurred in Griswoldville (population 350), the largest of the three mill villages. Seventeen cases occurred in the village of Shelburne Falls, a manufacturing town with a population of 2,500, which includes the villages of Shelburne Falls and Buckland, which are separated by the Deerfield River only. Six cases occurred in Turners Falls, a large manufacturing town on the Connecticut River, and 2 cases were in other towns across the river. The other cases were distributed in neighboring small towns.

Fifty-two of the 66 cases were located in the valley on these streams, while 10 of the remainder were hill cases in country districts adjacent to these towns. There were 3 scattered cases in Greenfield. The distribution of the cases is as follows: —

On the North River,	23
Hill cases adjacent,	5
On the Deerfield River (Shelburne Falls-Buckland),	13
Hill cases adjacent,	4
On the Falls River,	6
On the Connecticut River,	5
On the Connecticut River canal (Turners Falls),	2
On the Millers River,	2
Hill case adjacent,	1
On the Deerfield River (Deerfield),	1

The actual distance from the houses where the cases occurred to these streams above mentioned, including millponds, canals, etc., was found to be as follows: 4 cases were one-quarter of a mile distant; 15 cases were one-eighth of a mile distant; 33 cases were less than 500 feet distant, of which 20 cases were from 10 to 200 feet distant.

The relation of the hill cases to those in the valley was noted, and in every case it was found that the hill cases gave a history of visiting, driving or in some way spending time in the nearby towns, which were upon the streams, as above mentioned. A trolley line runs through the North River valley connecting Colrain and Shelburne Falls, and there is also trolley connection between Greenfield, Turners Falls and Millers Falls. Transportation for the hill cases to the river towns was by wagon only. It may be stated that there was no case in the 66 under consideration which had not been exposed recently to the valley influences, if any.

In addition to the above 69 cases in western Massachusetts, 6 cases of infantile paralysis occurred in southern Vermont in territory contiguous to the Colrain district. They all appeared to be independent cases, and [illegible] of them were located near the Deerfield River or its branches.

Sequence of Cases.

Sixty-five of the cases occurred in the summer months, as follows: [illegible] 6; July, 28; August, 26; S[illegible]r, 5; [illegible] isolated cases [illegible] in March, 1; April, 1; [illegible] height of [illegible] occurred [illegible] peak appears to be [illegible] between J[illegible] [illegible] towns, as follow[illegible] [illegible] Falls, 1; [illegible] throughout the [illegible]

district June 4 (the earliest case), in the Shelburne Falls district June 20, in the Colrain district July 1 (in the southern part of this territory) and July 4 (in the northerly part of this section).

The following table shows the sequence of cases as to time of onset: —

Date.	Town.	Case Number.
March 25,	Heath,	39x
April 1,	Heath,	39
June 4,	Montague (Turners Falls),	1
June 9,	Montague (Turners Falls),	2
June 13,	Montague (Turners Falls),	3
June 17,	Greenfield,	11
June 20,	Shelburne,	26
June 27,	Shelburne,	27
July 1,	Colrain (Shattuckville),	45
July 2,	Montague (Turners Falls),	4
July 4,	Colrain (Willis Place),	60
July 5,	Gill,	10
July 6,	Montague,	5
July 7,	Colrain (Frankton),	40
July 9,	Greenfield,	13
July 11,	Colrain (Griswoldville),	49
July 16,	Colrain (Frankton),	41
July 16,	Colrain (Shattuckville),	43
July 17,	Colrain (Shattuckville),	44
July 18,	Colrain (Griswoldville),	50
July 19,	Colrain (Griswoldville),	53
July 20,	Shelburne Falls,	25
July 20,	Montague,	6
July 20,	Colrain (Griswoldville),	51
July 23,	Colrain,	63
July 23,	Bernardston,	17
July 24,	Buckland,	29
July 25,	Shelburne Falls,	23
July 25,	Buckland,	32
July 25,	Colrain (Frankton),	42
July 25,	Buckland,	36
[illegible]	Bernardston,	15
[illegible]	Bernardston,	16
[illegible]	Colrain (Griswoldville),	54
[illegible]	Colrain (Willis Place),	59

Fifty-two of the 66 cases were located in the valley on these streams, while 10 of the remainder were hill cases in country districts adjacent to these towns. There were 3 scattered cases in Greenfield. The distribution of the cases is as follows: —

On the North River,	23
Hill cases adjacent,	5
On the Deerfield River (Shelburne Falls-Buckland),	13
Hill cases adjacent,	4
On the Falls River,	6
On the Connecticut River,	5
On the Connecticut River canal (Turners Falls),	2
On the Millers River,	2
Hill case adjacent,	1
On the Deerfield River (Deerfield),	1

The actual distance from the houses where the cases occurred to these streams above mentioned, including millponds, canals, etc., was found to be as follows: 4 cases were one-quarter of a mile distant; 15 cases were one-eighth of a mile distant; 33 cases were less than 500 feet distant, of which 20 cases were from 10 to 200 feet distant.

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In addition to the above 69 cases in western Massachusetts, 6 cases of infantile paralysis occurred in southern Vermont in territory contiguous to the Colrain district. These all appeared to be independent cases, and 4 of them were located near the Deerfield River or its branches.

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Sixty-five of the cases occurred in the summer months, as follows: June, 6; July, 28; August, 26; September, 5; while isolated cases occurred in March, 1; April, 1; and in November, 2. The height of the outbreak appears to have been July 25, on which date 6 cases occurred in 4 towns, as follows: Bernardston, 2 (one family); Buckland, 2; Shelburne Falls, 1; Colrain, 1. The early cases occurred at various points throughout the district concerned, as follows: [illegible] Falls

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June 13,	Montague (Turners Falls),	3
June 17,	Greenfield,	11
June 20,	Shelburne,	26
June 27,	Shelburne,	27
July 1,	Colrain (Shattuckville),	45
July 2,	Montague (Turners Falls),	4
July 4,	Colrain (Willis Place),	60
July 5,	Gill,	10
July 6,	Montague,	5
July 7,	Colrain (Frankton),	40
July 9,	Greenfield,	13
July 11,	Colrain (Griswoldville),	49
July 16,	Colrain (Frankton),	41
July 16,	Colrain (Shattuckville),	43
July 17,	Colrain (Shattuckville),	44
July 18,	Colrain (Griswoldville),	50
July 19,	Colrain (Griswoldville),	53
July 20,	Shelburne Falls,	25
July 20,	Montague,	6
July 20,	Colrain (Griswoldville),	51
July 23,	Colrain,	63
July 23,	Bernardston,	17
July 24,	Buckland,	29
July 25,	Shelburne Falls,	23
July 25,	Buckland,	32
July 25,	Colrain (Frankton),	42
July 25,	Buckland,	36
July 25,	Bernardston,	15
July 25,	Bernardston,	16
July 27,	Colrain (Griswoldville),	54
July 29,	Colrain (Willis Place),	59

Fifty-two of the 66 cases were located in the valley on these streams, while 10 of the remainder were hill cases in country districts adjacent to these towns. There were 3 scattered cases in Greenfield. The distribution of the cases is as follows: —

On the North River,	23
Hill cases adjacent,	5
On the Deerfield River (Shelburne Falls-Buckland),	13
Hill cases adjacent,	4
On the Falls River,	6
On the Connecticut River,	5
On the Connecticut River canal (Turners Falls),	2
On the Millers River,	2
Hill case adjacent,	1
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July 7,	Colrain (Frankton),	40
July 9,	Greenfield,	12
July 11,	Colrain (Griswoldville),	49
July 16,	Colrain (Frankton),	41
July 16,	Colrain (Shattuckville),	43
July 17,	Colrain (Shattuckville),	44
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July 19,	Colrain (Griswoldville),	53
July 20,	Shelburne Falls,	25
July 20,	Montague,	6
July 20,	Colrain (Griswoldville),	51
July 23,	Colrain,	68
July 23,	Bernardston,	17
July 24,	Buckland,	30
July 25,	Shelburne Falls	23
July 25,	Buckland,	32
July 25,	Colrain (Frank[illegible]	42
July 25,	Buckland,	36
July 25,	Bernardston,	[illegible]
July 25,	Bernard[illegible]	16
July 27,	Colrai[illegible]	[illegible]
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July 16,	Colrain (Frankton),	41
July 16,	Colrain (Shattuckville),	43
July 17,	Colrain (Shattuckville),	44
July 18,	Colrain (Griswoldville),	50
July 19,	Colrain (Griswoldville),	53
July 20,	Shelburne Falls,	25
July 20,	Montague,	6
July 20,	Colrain (Griswoldville),	51
July 23,	Colrain,	63
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July 25,	Buckland,	32
July 25,	Colrain (Frankton),	42
July 25,	Buckland,	36
July 25,	Bernardston,	15
July 25,	Bernardston,	16
July 27,	Colrain (Griswoldville),	54
July 29,	Colrain (Willis Place),	59

Date.	Town.	Case Number.
July 29,	Shelburne Falls,	22
Aug. 2,	Colrain (Griswoldville),	56
Aug. 3,	Colrain (Shattuckville),	47
Aug. 3,	Colrain (Shattuckville),	46
Aug. 5,	Colrain (Griswoldville),	48
Aug. 7,	Greenfield,	14
Aug. 7,	Cheshire,	64
Aug. 7,	Colrain (Lyonsville),	61
Aug. 8,	Buckland,	26
Aug. 9,	Greenfield,	12
Aug. 11,	Bernardston,	18
Aug. 11,	West Hawley,	67
Aug. 12,	Colrain (Griswoldville),	57
Aug. 12,	Montague,	7
Aug. 12,	Buckland,	30
Aug. 15,	Buckland,	35
Aug. 16,	Adams,	66
Aug. 18,	Erving (Millers Falls),	8
Aug. 22,	Shelburne Falls,	24
Aug. 23,	Heath,	37
Aug. 23,	Shelburne Falls,	21
Aug. 23,	Shelburne Falls,	20
Aug. 23,	Colrain (Willis Place),	58
Aug. 24,	Colrain (Adamsville),	62
Aug. 24,	Colrain (Griswoldville),	55
Aug. 27,	Colrain (Griswoldville),	52
Aug. 29,	Buckland,	31
Sept. 4,	Bernardston,	19
Sept. 8,	Deerfield,	14x
Sept. 23,	Buckland,	33
Sept. 25,	Buckland,	34
Sept. 29,	Heath,	38
Nov. 3,	North Adams,	65
Nov. 6,	Erving (Millers Falls),	9

From this table it appears that the outbreak in the various towns, with the exception of a few small groups, was not an explosive one, but cases occurred from time to time, covering a period of from six to eight weeks in each town. The sequence of cases in groups is shown in detail under "Contact and Relation of Cases."

Contact and Relation of Cases to Each Other, taken up by Groups.

Turners Falls Village. — The first cases out of the whole number occurred in Turners Falls Village on June 4, 9 and 13. These cases came down five days apart, and it is probable that there was indirect contact between the three families, although the contact between these 3 cases was very slight, if any. Case No. 1, June 4, was near the middle of a thirty-tenement block, and was the only case in the block or on the street. Case No. 2, June 9, was on the next street, in a four-tenement house, while Case No. 3, June 13, was in the middle of a thirty-tenement block next to the tenement house just mentioned. Case No. 1 was certainly an independent case, and probably case No. 3, while case No. 2 may not have seen case No. 1.

Independent case, 1. Contact cases, 2.

Turners Falls Suburbs. — Cases No. 11, June 17, No. 4, July 2, No. 10, July 5, and No. 5, July 6, were all independent cases, and were scattered in the suburbs of the village of Turners Falls, 3 being in Turners Falls, 1 in Greenfield and 1 in Gill, all within a mile and a half circle. Case No. 6, July 20, was a cousin of case No. 5, and lived on the second floor of the same tenement. These families were intimate, but as the children were five and eight months old, respectively, they were kept in their carriages, and there was no intimate contact between them.

Independent cases, 4. Contact case, 1.

Greenfield-Deerfield. — Case No. 13, July 9, No. 14, August 7, and No. 12, August 9, were all independent cases in Greenfield, one-half to one mile apart. No. 14x, September 8, was also an independent case, living in Deerfield.

Independent cases, 4.

Bernardston. — Two cases occurred at the same time in one family, Nos. 15 and 16, July 25. At the same time an older brother of nineteen, case No. 17, came home from logging with a headache, and went to bed and was supposed to have typhoid fever. His history and the atrophy of muscles in his right hand showed that he had infantile paralysis. A mile above this house was case No. 18, August 11. Three weeks later, September 4, a brother, case No. 19, was taken ill, having been, of course, in close contact with case No. 18.

Independent cases, 4. Contact case, 1.

Shelburne Falls. — The first case, No. 26, in this group was a primary case, and occurred June 20 on a mountain farm four miles from Shelburne Falls. There was intimate contact with a brother of fourteen and a sister of two, but not with a brother of twenty-two, who was work-

ing hard haying. Seven days later, however, he was taken sick, case No. 27, June 27. Cases No. 25, July 20, No. 23, July 25, No. 22, July 29, and No. 20 and No. 21, taken ill on the same day, August 23, were all independent cases. No. 20 and No. 21 had been more or less intimate up to the time of illness. Case No. 24, taken sick August 22, was visiting in Shelburne Falls and went daily across the river to a cousin in Buckland who was sick, case No. 36.

Independent cases, 6. Contact cases, 2.

Buckland. — Case No. 29, July 24, living on a mountain two miles from the village, was an independent case, as were cases No. 32, July 25, No. 36, July 25, No. 30, August 12, No. 31, August 29, and No. 33, September 23, living in the village. Within a day or two of the onset of case No. 33, his brother, case No. 34, was taken sick. As the history was difficult to get it cannot be stated whether his illness was coincident or a day or two later. Case No. 28, August 8, had been in contact with case No. 36, living two doors above, and was taken sick two weeks later.

Independent cases, 6. Contact cases, 2.

Colrain. — This town lies about one mile above Shelburne Falls and consists, as previously stated, of five villages: Frankton, Shattuckville, Griswoldville, Willis Place and Colrain City in the narrow North River valley. The largest number of cases was in the middle settlement, Griswoldville, and there were none in the settlement farthest north, Colrain City.

Frankton. — The Frankton group, consisting of three cases, Nos. 40, 41 and 42, had their first symptoms nine days apart, July 7, 16 and 25. These cases lived in three houses, about seventy-five feet apart. The first case, No. 40, was independent. No. 41, a child of two, had been carried by its mother when she went to inquire for No. 40, but there was no intimate connection between the children. There was an indefinite history of commingling of all the children, and No. 43 may have been in the house of No. 42 while she was ill. No. 43 was, however, recovering from a severe burn, and it is not probable that she was with the other cases while she was sick.

Independent case, 1. Contact cases, 2.

Shattuckville. — About one mile above Frankton occurred 6 cases 2 of which, No. 43 and No. 44, were in one family and were coincident, July 16 and 17. Two others, No. 46 and No. 47, were coincident cases in another family, August 3. No. 45, July 1, was an independent case, as was No. 48, taken ill August 5.

Independent cases, 6.

Griswoldville. — From one-half to a mile above Shattuckville is the village of Griswoldville, consisting of one street in a very narrow valley.

Nine cases occurred here, of which No. 49, July 11, No. 50, July 18, No. 53, July 19, No. 54, July 27, No. 56, August 2, No. 55, August 24, and No. 52, August 27, were probably independent cases, there being no history of contact of these children with each other while ill. Case No. 51 had played a little with case No. 50, but had not seen her after she, No. 50, was taken sick, and she may be considered an independent case, being a member of the family of the owner of the mills and knowing none of these other children. Case No. 57, however, a girl of sixteen, had been taking care of case No. 56, her sister of six, and was taken sick ten days after her younger sister.

Independent cases, 8. Contact case, 1.

Willis Place. — About a mile above Griswoldville is a large twenty-seven-tenement block. At one end of this block case No. 60 was taken sick July 29 and case No. 58 at the other end of the block August 23. There was no visiting between these families after the first case was taken sick and they appear to be independent cases.

Independent cases, 3.

The 54 cases just reviewed constitute what may be called the group cases, of which 43 are independent and 11 are possible contact cases, — 7 of which are of known and 4 of possible contact. The 15 remaining cases are all independent, 9 of which are connected by location with the groups above mentioned and 6 are isolated.

Independent Cases.		
Group,	43	
Connected with the group,	9	
Isolated,	6	
	—	58
Contact Cases.		
Known,	7	
Possible,	4	
	—	11
		—
Total,		69

Two cases in same family, coincident,	3
Three cases in same family, coincident,	1
Two cases in same family, not coincident,	[1] 4

[1] One of these consisted of two families, married sisters, living on the first and second floors of same house.

Time Interval.

The time interval elapsing between the exposure and onset of symptoms of the 7 cases of known contact is as follows: 3 cases of intimate contact with intervals of twenty-four days, fourteen days and eight days; 4 cases of contact not intimate, fourteen days, nine days (two instances) and seven days. In the 4 cases of probable contact the history is too indefinite to make it worth while to estimate this time interval.

Evidence of Contagion.

The following are the facts in relation to the 7 cases of known contact: case No. 6 was a female infant of five months, one of three children living in an upper tenement. She was taken ill fourteen days after her cousin, a female infant of eight months, was attacked who lived on the first floor of the same house. It is known that the infants were in the same room during the illness of the one first affected, but they were not in the same carriage or together on the same bed. Case No. 19 was a ten-year-old brother of case No. 18, and was taken sick twenty-four days later. There was no isolation, and two boys in the family were more or less intimate with the sick one. Case No. 24 shows the most intimate contact of any. She was a fifteen-year-old girl, and came to see her cousin, a boy of two, every day. She took care of him, sat by him and kissed him. Her first visit to him was three weeks after he was taken sick, when the acute symptoms had disappeared. Her first symptoms began eight days after she had first seen him. Case No. 27 was a strong farmer lad twenty-two years old. He was taken sick one week after his brother of four years. This boy was kept in the living rooms, and was intimate with two small children, but there was no intimate contact between him and the older brother, as he was very busy haying. Case No. 28, a girl of ten, lived two doors from case No. 36, a child of two years, and was a frequent visitor to this child, but she did not kiss him. Her first symptoms began fourteen days after the onset of symptoms in the little boy. Case No. 41 had been taken in its mother's arms when she went to inquire for the first case in this group, case No. 40, and may have been in the house several times, but there was no very intimate contact between them. She showed signs of the disease nine days after the onset of case No. 40. Case No. 57 was a girl of sixteen who had been taking care of her sister, No. 56, and had been sleeping with her throughout her illness. Her first symptoms were ten days after the onset of the first case in the family.

Evidence of Noncontagion.

Out of the whole number of cases there were but 2 that were isolated during their illness. One was in a family in which there were no other children and 1 was in a house in which there were three children, and this case was as thoroughly isolated as if it were a case of scarlet fever. The remaining 67 cases were not isolated in any degree, except that in a few instances the serious illness of the child was a sufficient bar to any intimate contact with the other children in the family.

Careful inquiry into the conditions that obtained during the illness of the 67 in which there was no isolation shows that there were 166 children in these families, 4 of which later had the disease; that there were 4 instances in which the sick child slept with a brother or sister up to the time of illness, 7 during the first few days of illness and 5 throughout the entire illness; that there were 9 instances in which the other children of the family drank from the same cup; that there were 12 instances in which the children in the family and neighbors' children kissed the sick child during the acute illness. It is impossible to determine the number of times that contact of the kind just mentioned occurred, but the above detail indicates to how great an extent the intimacy of the well with the sick did occur. Out of the entire number involved in the intimate contact just described 2 cases developed the disease.

Investigation further showed that there were, in addition to the 166 exposed children in the families, 86 children among neighbors and friends (making a total of 252 children) who were in intimate contact with the 67 cases. By intimate contact is meant (and this appeared to be almost universal) as free intercourse of the well and the sick as the patient's condition would permit. Playing with the child, sitting beside him and taking naps lying on the lounge or bed with him were the conditions that existed in almost every case. The total number of children that were more or less intimately exposed to the 67 cases is probably at least twice or three times the number of known exposures.

Diet.

Investigation of the diet showed the following: general diet, 58; cow's milk exclusively, 4; breast milk and cow's milk, 3; breast milk and fruit, etc., 4. Milk was found to be used in considerable quantities by 29 cases, in small amounts by 26, while 3 cases used no milk at all. Nineteen families produced their own milk, and there were twenty-two milkmen serving thirty-six families, while the milk for the remainder of the cases was brought from various sources. None of the infants under one year of age were fed upon breast milk alone.

Unusual Diet.

It was not found possible to get a more detailed history of the diet than is given above, except that in 6 cases it was especially mentioned that fruit and berries had been a very large item of diet. In the 2 infants, five and eight months old, bananas and berries were given as the diet in addition to breast milk. In 1 case the illness was attributed to eating heartily of English mulberries, and in 3 cases to the eating of large amounts of blackberries and blueberries. In 39 instances it was stated that food supplies were bought from pedlers, and it was found that these carts frequently served the town and country districts in their localities.

Preceding Illness.

Practically all the cases had been in good health previous to this attack. One child was in very feeble health, 5 were in a more or less run-down condition and 63 were in their usual condition, or good health. (One had recovered two months before from a slight attack of scarlet fever.)

Conditions immediately preceding Onset.

Traumatism. — There were 3 cases of traumatism as follows: fall from bicycle three weeks before illness; fall from piazza four weeks before illness; burn of arm and chest three weeks before illness. There were no special symptoms subsequent to the two falls, and the burn was healing properly when infantile paralysis developed.

Overheating. — Five cases gave a history of possible overheating within a day or two of the onset of the disease.

Fatigue. — Four cases were noted as suffering from marked fatigue within a day or two of this illness. One was a child of seven, who had been carrying bricks up a ladder the day before he was taken ill; another was a young man of eighteen who was a noted athlete; a third had been lifting very heavy weights, and a fourth was tired out with school work.

Swimming. — Five cases had been in swimming in the streams near by and 6 cases, among children, had been playing in the brooks, ponds, etc.

One child had a severe cold just before the symptoms of this disease appeared. It was noted in one case, in a young man of nineteen years old, that he had been extremely nervous and very much worried for fear he would develop this disease, as he had recently attended a funeral of a classmate who died from infantile paralysis.

Abortive Cases.[1]

There were 6 cases reported which on investigation were found to have the same acute symptoms as the other cases, but to a less degree, and no paralysis occurred. The history of these cases seemed to eliminate the possibility of their being simple gastro-intestinal disturbances; and while the diagnosis of infantile paralysis cannot be proven, the history of the cases seemed to warrant their being considered as abortive cases of this disease. One case occurred in a family more than three weeks after the onset of a rather severe case in another brother. One case was coincident (doubtful history) with that of an older brother, while 4 cases occurred without known exposure.

Symptoms accompanying Attack.

Pain, more or less marked, 62 cases; pain, little or none, 7 cases; fever, 63 cases; constipation, 47 cases; diarrhœa, 2 cases; nausea and vomiting, 43 cases; retraction of head, 35 cases; retention of urine, 23 cases; incontinence of urine, 1 case; brain symptoms, 13 cases; stiffness of neck, 6 cases; stiffness of spine, 7 cases.

Onset.

The onset in 65 cases was sudden and in 4 cases it was delayed, extending over several days.

Complicating Symptoms.

In 1 case a marked urticaria was an initial symptom; in 2 cases intense pain in the stomach was noted, also, as an initial symptom; in 5 cases a complicating tonsilitis was present; in 1 case a severe nose bleed took place; an extremely offensive breath was noted once; double vision occurred once as did also marked disturbance of speech. The early symptoms in 1 case were thought to be due to swollen glands, which had been present for a year, and in another case to a rheumatic condition. In 2 cases stumbling of the child while walking and playing was one of the first symptoms noted.

Diagnoses made.

In 1 case no diagnosis whatever was made; in 2 cases a diagnosis of typhoid fever was made, and the following diagnoses of single cases: digestive disturbance, heat stroke, cerebro-spinal meningitis, rheumatism.

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[1] This type of the disease is recognized and described by Wickman.

Recovery.

Excluding the 6 abortive cases, 58 cases were examined in this regard about nine months after the illness. Six cases appeared to have completely recovered from the paralysis. Six others appeared to have recovered, but of these, 5 were infants and could not be satisfactorily examined, while the other was sick at the time of examination. These 6 cases were classed as apparent recovery. Forty-two cases had partially recovered from paralysis, while 4 cases had shown but very slight improvement since the attack.

Deaths.

There were 5 fatal cases, 1 of which made a partial recovery and died two months later of broncho-pneumonia. The length of the illness in days was as follows: female, eight months, 65 (broncho-pneumonia); male, three years, 6; female, four years, 4; female, fifteen years, 5; male, nineteen years, 6.

Age and Sex.

Forty-two were males and 27 were females. This epidemic was characterized by the number of cases in middle and late childhood and young adult life. It will be noticed that there were 6 cases over seventeen years of age, all in males. The following table shows the age and sex of each case: —

	Males.	Females.	Totals.
Under one year,	2	5	7
One year,	1	4	5
Two years,	5	4	9
Three years,	7	1	8
Four years,	5	3	8
Five years,	-	2	2
Six years,	2	1	3
Seven years,	5	1	6
Eight years,	2	-	2
Nine years,	1	1	2
Ten years,	1	1	2
Twelve years,	1	-	1
Thirteen years,	1	-	1
Fourteen years,	2	-	2
Fifteen years,	-	2	2
Sixteen years,	-	1	1
Seventeen years,	-	1	1
Eighteen years,	1	-	1
Nineteen years,	2	-	2
Twenty years,	1	-	1
Twenty-one years,	1	-	1
Twenty-two years,	1	-	1
Twenty-five years,	1	-	1
Totals,	42	27	69

Nativity.

The following data were obtained: —

Nativity.

	Massachusetts.	United States.	Foreign.	Not obtained.
Father,	29	41	14	14
Mother,	29	44	17	8

Number of Birth.

	1st.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	10th.	11th.	Not obtained.
Cases,	14	13	16	8	7	4	2	1	1	1	7

Interval of Time to Previous Confinement, in Years.

	1	2	3	4	5	6	7	10
Cases,	18	18	7	3	1	2	2	2

Distribution of Paralysis.

With the exception of the 6 abortive cases which showed no paralysis, the distribution of the paralysis was as follows: —

General,	3
Neck and back,	1
Right forearm,	1
Right arm,	4
Left arm,	2
Both arms and legs, neck and back,	1
Both arms, back, chest and throat,	1
Right arm and right leg,	3
Right arm and left leg,	2
Left arm and left leg,	2
Left arm, left thigh and leg,	1
Right arm, right thigh and leg,	1
Left arm and right upper arm,	1
Right leg,	2
Left leg,	2
Both legs,	11
Both legs and left arm,	2

Both legs, left arm and back,	1
Both legs and back,	1
Both legs, left arm and neck,	2
Both legs, neck and back,	1
Both legs and thighs,	8
Both legs, left face and left arm,	1
Left leg and thigh,	5
Right leg and thigh,	2
Right leg and thigh and left face,	2

School.

As the outbreak occurred in July and August there were no results that could be attributed to school influences, and but 3 of the children attended school.

Weather.

A study of the plotted curves of temperature, rainfall (secured from the report of the Hatch Experiment Station at Amherst) and the number of cases appears to show no correlation whatever.

Local Conditions.

Investigation of the home conditions of each case shows that the sanitary conditions were found to be excellent in 4 cases, good in 17, fair in 31 and bad in 17.

Forty-one of the cases lived in detached houses, 17 in two-tenement and three in three-tenement houses, while but 8 lived in houses having four or more tenements.

The elevation of the dwelling was noted as high in 28 cases, as medium in 22 and low in 19.

Forty-two of the houses were considered to be dry, while 27 were noted as being in a more or less damp location. There were cellars in all of the houses, 42 of which were dry and 23 were damp, while 4 were found to be very damp or wet.

The water supply was given as spring water in 53, as the town supply in 14 and from wells in but 2 cases.

The sanitary arrangements in the houses showed that 23 houses had water-closets connected with the sewer and 46 had earth closets; that the sink water from 30 houses was carried into the sewer and in 39 cases it was disposed of in various ways on the land near by or in pipes to the nearest brook, pond, etc.

Screens were found to be used in 65 cases and not used in but 4 cases. Inquiry into the question of flies and mosquitoes showed that flies were said to be numerous in 28 instances, few in 39 and not present in 2;

that mosquitoes were said to be numerous in 22 instances, few in 44 and not present in 2. No history of insect bites at the time of illness was obtained.

Summary.

We are dealing with groups of cases of an acute disease attacking children chiefly, but youth and adults frequently up to the age of twenty-five years, among the inhabitants of river valleys in sparsely settled communities, occurring during the summer months of a hot, dry season. The persons attacked lived chiefly in detached houses, and but 8 lived in houses or blocks of more than three tenements. Although the cause of the disease is not known, it can undoubtedly be classed as infectious, as its distribution and incidence in localities are similar to those of other infectious diseases and strongly suggest a common cause.

Ninety per cent. of the persons attacked were in good health, and while a few instances of traumatism, overheating, fatigue and swimming were noted previous to the onset, the history of these cases does not seem to warrant the placing of much etiological responsibility upon these occurrences. They were not different from what might be found in the history of almost any groups of persons at this season.

With regard to the contagiousness of the disease the investigation of this group of cases suggests that the disease is but mildly contagious, to say the most. A large number of children were in intimate contact with those who were sick, and of these children an insignificant minority developed the disease. Although the group of cases investigated is a small one from which to draw generalizations, it must be remembered that the circumstances were particularly favorable to the investigation of points of contact between sick and well and of the detection of contagion.

The sanitary conditions under which most of the cases lived were not good. Dampness prevailed in many locations and most of the houses were very near water, but it must be remembered that the outbreak was in the valleys. Most of the houses had no sewer connection.

The marked digestive disturbances, which were early and notable symptoms, suggest the stomach as the port of entry for the infection. It does not seem possible in this outbreak to blame the varied sources of milk or water supply as carriers of the infection, unless it be considered that the cause of the disease may be present in all milk or in all water. That the cause may be connected with the food seems possible. It is important to note that none of the 7 infants under one year of age were fed exclusively upon breast milk.

The facts that all the cases living on the hill farms had been in the valley towns recently, where the infection may have occurred, and that

many families purchased some of their food supplies from pedler which act as the go-between between the town and the country, noteworthy.

It is not known what influences the dry season, with its low w the proximity of many houses to water, contributes, but these fact to be significant.

Conclusions.

From an intimate acquaintance with all the facts and condi this outbreak we conclude that: —

1. Infantile paralysis is a disease produced by some external a that is, it is an infectious disease.

2. It is mildly contagious at the most.

3. The harmful agent appears to enter the digestive tract instances.

4. Until the organism causing the disease is known, it will be sible to say whether the infection is carried directly to the pa by means of food.

GENERAL HEALTH OF THE STATE.

The number of deaths in the State in 1907 was 54,234, which was equivalent to a death-rate of 17.57 per 1,000 upon an estimated population of 3,086,885.

The mean death-rate of the five years 1903, 1904, 1905, 1906, and 1907 was 16.62, as compared with 17.20 for the previous five years.

The following figures are presented for the ten years ended with 1907: —

Massachusetts.

YEARS.	Population.[1]	Deaths.	Death-rates.	YEARS.	Population.[1]	Deaths.	Death-rates.
1898, ...	2,679,049	46,761	17.46	1903, ...	3,006,040	49,054	16.32
1899, ...	2,741,470	47,710	17.40	1904, ...	3,076,083	48,482	15.76
1900, ...	2,805,346	51,156	18.24	1905, ...	3,003,680	50,486	16.81
1901, ...	2,870,710	48,275	16.82	1906, ...	3,044,998	50,624	16.63
1902, ...	2,937,600	47,491	16.17	1907, ...	3,086,885	54,234	17.57

[1] Population estimated for intercensal years.

INFECTIVE DISEASES.

The death-rate from the principal infective diseases in 1907 varied somewhat from that of 1906. There was an increase in the number of deaths from diphtheria, scarlet fever, cancer, consumption, cholera infantum, cerebro-spinal meningitis and pneumonia, and a decrease in the deaths from measles, whooping cough, typhoid fever and dysentery. There were 6 deaths from smallpox.

The deaths and death-rates from each of the foregoing diseases in the past five years are shown in the following table: —

Deaths and Death-rates from Certain Diseases in Massachusetts, 1903–1907.

	1903.		1904.		1905.		1906.		1907.	
	Deaths.	Death-rates per 10,000.	Deaths.	Death-rates per 10,000.	Deaths.	Death-rates per 10,000.	Deaths.	Death-rates per 10,000.	Deaths.	Death-rates per 10,000.
Smallpox,	22	.07	9	.03	2	.007	-	-	6	.019
Diphtheria,	869	2.89	699	2.27	652	2.17	743	2.44	752	2.44
Scarlet fever,	510	1.70	138	.45	117	.39	135	.44	285	.92
Typhoid fever,	527	1.75	463	1.51	520	1.73	477	1.57	389	1.26
Measles,	247	.82	160	.52	177	.59	208	.68	163	.53
Cholera infantum,	2,469	8.21	2,297	7.47	2,617	8.72	2,525	8.29	2,696	8.73
Consumption,	4,531	15.07	4,874	15.84	4,702	15.67	4,608	15.14	4,771	15.46
Dysentery,	188	.63	184	.60	182	.60	176	.58	169	.55
Whooping cough,	519	1.73	117	.38	218	.73	509	1.67	243	.79
Pneumonia,	5,190	17.27	5,100	16.58	5,378	17.93	5,377	17.65	5,709	18.50
Cancer,	2,243	7.46	2,421	7.87	2,501	8.33	2,603	8.55	2,744	8.89
Cerebro-spinal meningitis,	156	.52	165	.54	560	1.87	368	1.21	434	1.41

In the following table a balance is presented between the deaths from the principal infective diseases in the two years 1906 and 1907, by which it appears that the sum of the deaths from these twelve causes in 1907 was higher by 632 than those of 1906 from the same causes: —

Deaths from Certain Infective Diseases in 1906 and 1907.

Diseases.	1906.	1907.	Increase.	Decrease.
Smallpox,	-	6	6	-
Diphtheria and croup,	743	752	9	-
Scarlet fever,	135	285	150	-
Typhoid fever,	477	389	-	88
Measles,	208	163	-	45
Cholera infantum,	2,525	2,696	171	-
Consumption,	4,608	4,771	163	-
Dysentery,	176	169	-	7
Whooping cough,	509	243	-	266
Pneumonia,	5,377	5,709	332	-
Cancer,	2,603	2,744	141	-
Cerebro-spinal meningitis,	368	434	66	-
Totals,	17,729	18,361	1,038	406

Infant Mortality.

The rate of infant mortality during the year 1907 was, generally, much lower than that which prevailed during the five years 1902, 1903, 1904, 1905, and 1906, it being 135.7 for the year 1907, as compared with 144.7 for 1906, 141.4 for 1905, 133.6 for 1904, 139.5 for 1903, and 140.4 for 1902.

The total number of births which occurred during the year ended June 30, 1907, was 83,230, and the total deaths under one during the year ended Dec. 31, 1907, were 11,293.

For the sake of accuracy the death-rate of infants under one year old is obtained by comparing the deaths of such infants occurring in a year with the mean number of infants under one living throughout a year, and this number must "lie between the annual number of births and that number diminished by the deaths under one. It would be nearer the latter than the former number on account of the excess of deaths in the first months of life" (Dr. Farr). In the following table the births in the first line are those which occurred between July 1, 1897, and June 30, 1898, inclusive, and so on through the table, the births in the last line being those for the year ended June 30, 1907.

The deaths under one in the same table are those of the calendar years ended Dec. 31, 1898, 1899, etc. The births during these ten years were 744,539, and the deaths under one year were 106,250, which is equivalent to an infant mortality-rate of 142.7 per 1,000 births for the decade. The last half of the period shows a gain over the first half, since the infantile death-rate in the last five years was 138.9 per 1,000 births, as compared with 146.7 in the first five years.

Infant Mortality, Massachusetts: 1898–1907, Ten Years.

Years.	Births in Year ending June 30.	Deaths under One Year.	Death-rate under One Year per 1,000 Births.	Years.	Births in Year ending June 30.	Deaths under One Year.	Death-rate under One Year per 1,000 Births.
1898, . .	73,868	11,012	149.1	1903, . .	73,618	10,269	139.5
1899, . .	71,156	10,532	148.0	1904, . .	74,791	9,992	133.6
1900, . .	72,430	11,500	159.0	1905, . .	74,387	10,519	141.4
1901, . .	72,559	9,952	137.2	1906, . .	76,730	11,106	144.7
1902, . .	71,770	10,075	140.4	1907, . .	83,230	11,293	135.7

Total births in ten years ended June 30, 1907, 744,539.
Total deaths under one in ten years ended Dec. 31, 1907, 106,250.
Mean infantile death-rate, 142.7 per 1,000 births.

Consumption.

The total number of deaths from this cause registered in 1907 was 4,771, an increase of 164 deaths from the number of deaths occurring from this disease in 1906. The death-rate from consumption was less

in 1907 than that of any year of record, except that of the years 1903 and 1906, when the death-rate was 15.1.

The following figures present the deaths and death-rates, by ten-year periods, during the half century 1851–1900, and for the single years 1901, 1902, 1903, 1904, 1905, 1906, and 1907: —

Deaths and Death-rates from Consumption in Massachusetts, 1851–1907.

Periods.	Deaths.	Death-rates per 10,000.	Periods.	Deaths.	Death-rates per 10,000.
1851-60,	45,252	39.9	1902,	4,685	15.9
1861-70,	45,913	34.9	1903,	4,531	15.1
1871-80,	54,039	32.7	1904,	4,874	15.8
1881-90,	58,308	29.2	1905,	4,702	15.7
1891-1900,	54,374	21.4	1906,	4,608	15.1
1901,	5,083	17.5	1907,	4,771	15.5

Typhoid Fever.

The following table presents the deaths and death-rates of the cities from this cause during the year 1907: —

Deaths and Death-rates from Typhoid Fever in the Cities of Massachusetts, 1907.

Cities.	Deaths from Typhoid Fever.	Death-rates per 10,000.	Cities.	Deaths from Typhoid Fever.	Death-rates per 10,000.
North Adams,	9	4.1	Gloucester,	3	1.2
Beverly,	5	3.2	Pittsfield,	3	1.1
Lawrence,	23	3.0	Boston,	64	1.0
Northampton,	6	2.9	Lowell,	10	1.0
Springfield,	23	2.9	Medford,	2	1.0
Waltham,	8	2.9	Brockton,	5	1.0
Salem,	10	2.6	Everett,	3	1.0
Haverhill,	9	2.4	Cambridge,	8	.8
Taunton,	7	2.3	Chelsea,	3	.8
Newburyport,	3	2.0	Woburn,	1	.7
Malden,	7	1.8	Melrose,	1	.7
Fall River,	18	1.7	Holyoke,	3	.5
Somerville,	12	1.7	Chicopee,	1	.5
Lynn,	14	1.7	Newton,	1	.3
Worcester,	20	1.5	Marlborough,	-	-
Fitchburg,	5	1.5	Quincy,	-	-
New Bedford,	10	1.3	Total,	297	-

Death-rate for the above 33 cities, 1907, 1.4.

Following is a condensed summary from the report of 1900, from which it can be seen that a decided and continuous improvement in the death-rate from typhoid fever is taking place: —

Death-rates from Typhoid Fever per 10,000, 1871-1907, Massachusetts.

1871-75,	8.2	1896-1900,	2.6
1876-80,	4.2	1901-05,	1.9
1881-85,	4.1	1906,	1.6
1886-90,	4.6	1907,	1.3
1891-95,	3.4		

For the entire State the death-rates from this cause in 1901, 1902, 1903, 1904, 1905, 1906, and 1907 were, respectively, 1.95, 1.83, 1.75, 1.75, 1.73, 1.57, and 1.26 per 10,000 inhabitants.

The highest death-rates from this cause among the cities appear to have occurred in North Adams (4.1), Salem (3.2), Lawrence (3.0), and Northampton (2.9); and the lowest occurred in Holyoke (0.5), Chicopee (0.5), and Newton (0.3). Marlborough reported 5 cases, and Quincy 25 cases of typhoid fever, with no deaths.

Diphtheria.

The following table shows the deaths and death-rates from diphtheria by five-year periods from 1876 to 1905, and for the years 1906 and 1907: —

Deaths and Death-rates from Diphtheria per 10,000, 1876-1907, Massachusetts.

Years.	Deaths.	Death-rates.	Years.	Deaths.	Death-rates.
1876-80,	13,676	15.8	1896-1900,	6,331	4.7
1881-85,	8,944	9.5	1901-05,	4,259	2.9
1886-90,	8,857	8.4	1906,	743	2.4
1891-95,	7,652	6.4	1907,	752	2.4

Further and more definite information relative to diphtheria may be found in that portion of the report which relates to the production and distribution of antitoxin.

Other Preventable Diseases.

The following table presents the deaths and death-rates from measles, scarlet fever, dysentery, cholera infantum, and whooping cough for the period of forty-two years, 1866–1907: —

Deaths and Death-rates in Massachusetts per 10,000 Living from Certain Infective Diseases by Five-year Periods, 1866-1905, and for the Years 1906 and 1907.

	Measles.		Scarlet Fever.		Dysentery.		Cholera Infantum.		Whooping Cough.	
	Deaths.	Death-rates.	Deaths.	Death-rates.	Deaths.	Death-rates.	Deaths.	Death-rates.	Deaths.	Death-rates.
1866-70, . .	1,061	1.6	4,670	6.8	3,244	4.7	6,943	10.1	1,481	2.1
1871-75, . .	1,133	1.4	6,782	8.6	2,191	2.8	12,453	15.8	1,561	2.0
1876-80, . .	742	.9	3,517	4.1	2,366	2.7	9,054	10.5	1,498	1.7
1881-85, . .	1,007	1.1	2,504	2.7	1,601	1.7	9,894	10.5	1,213	1.3
1886-90, . .	1,069	1.0	1,810	1.7	1,276	1.2	10,904	10.3	1,421	1.3
1891-95, . .	815	.7	2,857	2.4	1,063	.9	13,426	11.2	1,445	1.2
1896-1900, . .	948	.7	1,358	1.0	1,434	1.1	11,865	8.9	1,465	1.1
1901-1905, . .	1,090	.7	1,463	1.0	970	.7	13,245	9.1	1,401	1.0
1906, . . .	208	.7	135	.4	176	.6	2,525	8.3	509	1.7
1907, . . .	163	.5	285	.9	169	.6	2,696	8.7	243	.8

The deaths from cerebro-spinal meningitis were 434, a marked decrease from the number of deaths recorded in 1905, and represented a death-rate of 1.41 per 10,000 living. In 1906 the death-rate was 1.21.

There were 3 deaths from hydrophobia during the year, 31 from tetanus, 2 each from actinomycosis and anthrax and 1 each from glanders and malignant pustule.

WEEKLY MORTALITY RETURNS. — REPORTS OF CERTAIN INFECTIVE DISEASES. — REPORTS OF CITIES AND TOWNS, MADE UNDER THE PROVISIONS OF R. L., c. 75, § 52. — REPORTS MADE UNDER THE PROVISIONS OF R. L., c. 75, § 12.

The statistical information relating to disease and mortality which has been received by the Board during each year, either through the medium of voluntary returns or in consequence of legal requirements, has, in the recent reports of the Board, been presented under four different heads or groups. Since 1902, this series of statistics has been condensed as much as can be done consistently with a clear and intelligent method of presentation.

These summaries are defined as follows: —

I. *The Weekly Mortality Returns.* — These consist of the reports of deaths, which are made up weekly and are sent to the office of the State Board by the registration officials of cities and towns. They serve principally to show the seasonal prevalence of each of the chief infective diseases, and the mortality of children under five years old, in weekly periods. Beginning with the year 1875, this series of statistics has been

annually reported (see page 475 of report for that year), and was first published as a summary in the report of 1883.

II. *The Reports of Certain Infective Diseases, — Diphtheria, Scarlet Fever, Typhoid Fever and Measles.* — These are obtained from the reports of local boards of health forwarded during 1907 to the State Board as cases arose. By comparing the numbers of reported cases with the reported deaths, the mean fatality of each disease in the places from which the reports are made is obtained with a reasonable degree of accuracy.

III. *Reports of Cities and Towns, made under the Provisions of Chapter 75, Section 52, of the Revised Laws.* — By this act each local board of health is required to report to the State Board every case of "disease dangerous to the public health" which is reported to the local board. A digest of these reports is presented in Summary No. III. This summary was first published in the report of 1893, page 639.

IV. *Annual Reports made under the Provisions of Chapter 75, Section 12, of the Revised Laws.* — The full reports of deaths occurring in each city and town having over 5,000 inhabitants comprise another series of returns, which are summarized in No. IV. The population of these cities and towns, as estimated in 1907, constituted about 87 per cent. of the total population of the State. These reports are made under the requirements of the following statute: —

In each city and town having a population of more than five thousand inhabitants, as determined by the last census, at least one member of said board shall be a physician, and the board shall send an annual report of the deaths in such town to the state board of health. The form of such reports shall be prescribed and furnished by the state board of health. (Revised Laws, chapter 75, section 12.)

This summary was first presented in the report of 1894.

NOTE. — A supply of the postal cards, necessary for the reporting of voluntary mortality returns such as are required for the data presented in Section I. of the following summary, will be forwarded to the registration officers of any city or town who are willing to contribute the necessary information.

Postal cards are also sent to all boards of health in the State, for the purpose of aiding them to comply with the provisions of chapter 75, section 52, of the Revised Laws, relative to the reporting of diseases dangerous to the public health to the State Board immediately after reports of the same are received by the local board.

Annual blank forms are also sent to each local board of health in cities and towns having over 5,000 inhabitants, for the return of such information as is called for by the provisions of chapter 75, section 12, of the Revised Laws.

I.

The Weekly Mortality Returns.

In the following summary, the voluntary reports of deaths received at the close of each week from the city registrars, town clerks and boards of health of the cities and towns are epitomized for the year ended Nov. 30, 1908. The chief value of this abstract consists in the fact that it presents a continuous history of the mortality from certain specified diseases from week to week throughout the year.

This weekly report has been published in the Boston Medical and Surgical Journal every week for a period of twenty-five years or more, and also in a publication of the Board, a weekly bulletin, since and including 1883.[1]

These returns are necessarily incomplete, since they are voluntary and consequently embrace the statistics of only a portion of the population, the reporting places being chiefly the cities and large towns.

The population of the cities and towns contributing to these returns during the year was 2,302,823, or 74 per cent. of the total population.

The following items are embraced in this summary:—

Total deaths reported for each week.
Deaths of children under five years.
Deaths from acute lung diseases.
Deaths from consumption.
Deaths from diphtheria.
Deaths from typhoid fever.
Deaths from measles.
Deaths from cerebro-spinal meningitis.
Deaths from erysipelas.
Deaths from whooping cough.
Deaths from scarlet fever.
Deaths from influenza.
Deaths from smallpox.
Deaths from tuberculosis other than pulmonary.
Deaths from meningitis other than cerebro-spinal.

The following table contains a summary of the statistics compiled from these weekly returns of mortality:—

[1] The bulletin was changed from a weekly to a monthly publication in January, 1906.

Summary Dec. 7, 1907, to Nov. 28, 1908.

	Total Deaths.	Deaths under Five Years of Age.	Acute Lung Diseases.	Consumption.	Diphtheria.	Typhoid Fever.	Measles.	Cerebro-spinal Meningitis.	Erysipelas.	Whooping Cough.	Scarlet Fever.	Influenza.	Smallpox.	Tuberculosis, other than Pulmonary.	Meningitis, other than Cerebro-spinal.
1907.															
December 7,	724	158	118	58	12	9	5	6	2	-	7	-	-	-	-
14,	830	196	160	56	18	7	6	8	2	2	4	7	-	-	-
21,	881	240	159	51	12	5	12	7	2	3	10	8	-	-	-
28,	877	182	188	55	11	5	4	6	3	3	6	3	-	-	-
1908.															
January 4,	863	205	157	64	12	5	7	2	4	2	11	-	8	-	-
11,	859	296	151	74	9	2	9	5	5	2	8	5	-	-	-
18,	817	200	164	65	10	1	8	9	-	2	6	2	1	-	-
25,	796	280	185	61	13	3	11	5	3	3	12	-	-	-	-
February 1,	809	234	151	68	12	2	5	4	3	3	5	1	-	-	-
8,	844	258	164	62	14	3	5	5	3	3	7	-	1	-	-
15,	841	231	159	72	11	2	5	3	2	3	8	-	-	-	-
22,	750	205	154	60	11	3	10	7	2	5	10	-	-	-	-
29,	823	241	156	72	14	6	6	4	3	4	3	1	-	-	-
March 7,	759	195	111	81	11	2	4	5	2	2	7	-	-	2	-
14,	804	238	121	71	9	5	4	10	5	1	7	1	-	-	-
21,	758	229	132	61	15	2	4	6	3	3	12	-	-	-	-
28,	796	251	127	91	12	2	8	6	3	3	14	-	-	1	-
April 4,	796	241	142	76	11	4	8	5	3	4	8	-	-	-	-
11,	742	230	99	66	14	3	6	6	1	1	10	-	-	-	-
18,	808	239	124	76	7	22	10	5	6	2	8	-	-	1	1
25,	778	246	228	55	10	18	10	2	3	7	6	-	-	-	-
May 2,	809	243	121	77	8	26	5	2	4	2	10	-	-	-	-
9,	722	226	109	50	9	15	12	5	1	5	6	-	-	-	-
16,	747	195	61	70	9	12	10	3	2	1	8	-	-	-	-
23,	713	191	79	64	8	12	14	1	3	6	8	-	-	-	-
30,	690	222	52	60	6	14	21	5	2	3	15	-	-	-	-
June 6,	606	157	41	65	10	6	5	2	4	1	8	-	-	-	-
13,	571	155	35	49	10	4	12	3	1	1	5	-	-	-	-
20,	608	188	43	47	5	6	12	1	2	2	9	-	-	-	-
27,	687	219	36	58	11	4	5	4	1	2	6	-	-	-	-

Summary Dec. 7, 1907, to Nov. 28, 1908 — Concluded.

		Total Deaths.	Deaths under Five Years of Age.	Acute Lung Diseases.	Consumption.	Diphtheria.	Typhoid Fever.	Measles.	Cerebro-spinal Meningitis.	Erysipelas.	Whooping Cough.	Scarlet Fever.	Influenza.	Smallpox.	Tuberculosis, other than Pulmonary.	Meningitis, other than Cerebro-spinal.
July	4,	645	207	39	48	7	5	5	3	1	8	5	-	-	1	1
	11,	659	260	32	44	9	3	9	2	-	8	2	-	-	1	1
	18,	687	319	24	61	5	7	1	1	1	4	5	-	-	-	-
	25,	736	335	25	50	9	11	2	3	1	4	5	-	-	-	-
August	1,	697	309	22	50	6	6	7	2	1	6	1	-	-	-	-
	8,	697	333	29	108	6	4	1	2	5	6	4	-	-	-	-
	15,	763	376	32	55	1	7	2	2	-	5	2	-	-	-	-
	22,	776	369	35	51	8	6	-	3	1	5	3	-	-	-	-
	29,	742	322	39	52	10	9	1	-	1	3	2	-	-	-	-
September	5,	694	292	24	46	7	5	-	3	1	9	1	-	-	-	-
	12,	695	290	21	55	7	12	3	1	1	6	3	-	-	-	-
	19,	668	276	33	48	9	8	2	2	3	5	-	-	-	2	-
	26,	768	299	54	57	8	28	2	6	1	2	1	-	-	2	-
October	3,	658	288	50	75	10	4	1	1	-	2	1	-	1	-	-
	10,	665	245	45	46	13	9	1	1	-	4	1	-	-	-	2
	17,	627	238	48	56	16	9	2	3	-	2	1	1	-	-	-
	24,	613	196	48	41	13	6	4	2	-	2	1	-	-	-	1
	31,	691	202	71	57	15	14	-	2	-	3	1	-	-	-	1
November	7,	588	179	62	48	13	6	1	1	-	5	4	-	-	-	1
	14,	717	188	68	56	12	14	1	1	2	4	2	-	-	-	2
	21,	614	181	75	50	19	7	2	2	-	2	7	-	-	-	1
	28,	623	177	89	46	21	8	-	2	2	4	4	-	-	-	2
Totals,		38,075	12,265	4,618	3,117	543	396	290	187	101	195	300	29	6	10	13
Weekly average,		732	236	89	60	10.4	7.7	5.6	3.6	1.9	3.8	5.8	0.6	0.1	0.2	0.3
Rate per 1,000 deaths,		-	322.1	121.2	81.9	14.3	10.5	7.6	4.9	2.7	5.1	7.9	0.8	0.2	0.3	0.3
Rate per 1,000 population,		16.58	5.33	2.00	1.35	.24	.17	.13	.08	.04	.08	.13	.01	.003	.004	.006

Average reporting population, ... 2,302,828

Condensed Statistics embracing the Total Deaths, Deaths under Five Years, and Deaths from Certain Causes in Reporting Cities and Towns of Massachusetts for the Year ended Nov. 30, 1908.

	Deaths.	Average Number of Deaths in Each Week.	Percentage of Total Mortality.	Death-rate per 1,000 of Reporting Population.
Total deaths,	38,075	732	100.00	16.53
Deaths under five years,	12,265	236	32.21	5.33
Deaths from acute lung diseases,	4,613	89	12.12	2.00
Deaths from consumption,	3,117	60	8.19	1.35
Deaths from diphtheria,	543	10.4	1.43	0.24
Deaths from typhoid fever,	398	7.7	1.05	0.17
Deaths from measles,	290	5.6	0.76	0.13
Deaths from cerebro-spinal meningitis,	187	3.6	0.49	0.08
Deaths from erysipelas,	101	1.9	0.27	0.04
Deaths from whooping cough,	195	3.8	0.51	0.08
Deaths from scarlet fever,	300	5.8	0.79	0.13
Deaths from influenza,	29	0.6	0.08	0.01
Deaths from smallpox,	6	0.1	0.02	0.003
Deaths from tuberculosis other than pulmonary.	10	0.2	0.03	0.004
Deaths from meningitis other than cerebro-spinal.	13	0.3	0.03	0.006

II.

Fatality of Certain Diseases.

Since the year 1891 the following statistics relative to the fatality of certain diseases have been gathered from the published reports of local boards of health. Until the passage of the law in 1893 this was the only source from which figures could be obtained on which to base the fatality of diseases as compared with cases. When the law (chapter 302, Acts of 1893) requiring local boards of health to report all cases of contagious diseases to the State Board of Health first went into effect very few returns were made, and it was not until after public notice had been given by the State Board to every board of health throughout the State that these returns came in with any regularity. The practice by the local boards of health of reporting cases of contagious diseases is now so well established, and the returns are so complete, it is no longer deemed necessary to continue the former method of basing the fatality of certain contagious diseases on the figures obtained through the annual reports

of local boards, but, instead, to make use of the more complete returns as received from day to day at this office.

The diseases embraced in this summary in 1907 are diphtheria, scarlet fever, typhoid fever and measles.

The tabular list of cities and towns is omitted in this report. The summary of the figures for 1907 is as follows: —

Reported cases of diphtheria for the State,	8,962
Registered deaths from diphtheria,	752
Fatality (per cent.),	8.4
Reported cases of scarlet fever for the State,	7,931
Registered deaths from scarlet fever,	285
Fatality (per cent.),	3.6
Reported cases of typhoid for the State,	2,290
Registered deaths from typhoid fever,	389
Fatality (per cent.),	17.0
Reported cases of measles for the State,	6,487
Registered deaths from measles,	163
Fatality (per cent.),	2.5

The following table presents the summary of these statistics for the seventeen years 1891–1907: —

Reported Cases of Infective Diseases in Massachusetts.

Diphtheria.

[Pre-Antitoxin Period.]

	1891.	1892.	1893.	1894.	Total.
Reported cases,	2,444	3,033	2,919	4,986	13,382
Deaths,	575	891	926	1,376	3,76[illegible]
Fatality (per cent.),	23.5	29.2	31.7	27.9	2[illegible].3

Diphtheria.

[Antitoxin Period.]

	1906.	1907.	Total 1895–1907.
Reported cases,	8,305	8,962	96,960
Deaths,	743	753	11,3[illegible]
Fatality (per cent.),	8.9	8.4	11.[illegible]

Reported Cases of Infective Diseases in Massachusetts — Concluded.

Scarlet Fever.

	1906.	1907.	Total 1891-1907.
Reported cases,	5,223	7,931	89,196
Deaths,	135	285	4,587
Fatality (per cent.),	2.5	3.6	5.2

Typhoid Fever.

	1906.	1907.	Total 1891-1907.
Reported cases,	2,986	2,290	42,938
Deaths,	477	389	7,547
Fatality (per cent.),	16.0	17.0	17.6

Measles.

	1906.	1907.	Total 1891-1907.
Reported cases,	15,553	6,487	139,545
Deaths,	208	163	1,984
Fatality (per cent.),	1.3	2.5	1.4

In the foregoing tables the statistics relating to diphtheria have been arranged in two periods, which may properly be called the pre-antitoxin and the antitoxin periods, since antitoxin came into general use in the State about the beginning of the year 1895. For the latter period the figures for 1906 and 1907 are given and the total for the thirteen years 1895 to 1907, inclusive. The mean fatality in the former period (1891–1894) was 28.3 per cent. (ratio of deaths to cases), and in the latter period (1895–1907) it was 11.8 per cent., or less than half as large.

III.

Official Returns of Notified Diseases Dangerous to the Public Health, for the Year ended Nov. 30, 1908.

The figures presented in the following summary are those of the official returns of diseases "dangerous to the public health," made to the State Board of Health during the year ended Nov. 30, 1908, under the provisions of chapter 75 of the Revised Laws. In this act no disease is specified as being "dangerous to the public health" except smallpox. Hence the State Board deemed it necessary to indicate the diseases which should be included in the meaning of the term "dangerous to the public

health." They are the following: actinomycosis, Asiatic cholera, cerebro-spinal meningitis, diphtheria, glanders, leprosy, malignant pustule, measles, scarlet fever, smallpox, tetanus, trichinosis, tuberculosis, typhoid fever, typhus fever, varicella, whooping cough, yellow fever.

The whole number of cases of infective diseases reported to the Board in the year ended Nov. 30, 1908, under the provisions of this act, was 50,451, which was divided chiefly as follows: —

Reported cases of smallpox, ...	16
Reported cases of scarlet fever, ...	7,833
Reported cases of diphtheria, ...	8,939
Reported cases of typhoid fever, ...	3,639
Reported cases of measles, ...	21,745
Reported cases of cerebro-spinal meningitis, ...	205
Total, ...	42,377

The summary for the fifteen years and three months 1893–1908 is as follows: —

	Reported Cases of —						Totals.
	Smallpox.	Scarlet Fever.	Diphtheria.	Typhoid Fever.	Measles.	Cerebro-spinal Meningitis.	
1893 (four months only),	35	2,914	1,109	1,525	1,503	-	7,086
1894, ...	181	6,731	4,178	2,372	2,133	-	15,595
1895, ...	1	6,194	7,806	2,438	4,868	-	21,307
1896, ...	5	3,801	8,515	2,687	6,362	-	21,370
1897, ...	18	5,495	7,613	2,104	12,695	-	27,925
1898, ...	10	3,667	3,980	2,196	4,478	-	14,331
1899, ...	105	5,349	7,184	2,776	12,355	-	27,769
1900, ...	104	6,396	12,641	2,967	10,507	-	32,615
1901, ...	778	4,356	9,793	2,689	9,396	-	27,012
1902, ...	2,314	4,613	7,086	2,721	17,249	-	33,983
1903, ...	422	5,877	6,888	2,955	9,430	-	25,572
1904, ...	100	4,100	6,772	2,605	12,511	-	26,088
1905 (11 months), . .	44	3,594	5,059	2,794	6,107	455	18,053
1906 (Dec. 1, 1905–Nov. 30, 1906).	35	5,162	7,967	3,093	17,048	291	33,596
1907, ...	164	7,860	9,098	2,350	5,688	428	25,588
1908, ...	16	7,833	8,939	3,639	21,745	205	42,377
Totals, . . .	4,327	83,942	114,528	41,861	154,077	1,379	400,114

By months these diseases were reported as follows: —

Cases of Infective Diseases reported to the State Board of Health by Months from Dec. 1, 1907, to Nov. 30, 1908.

Months.	Smallpox.	Scarlet Fever.	Diphtheria.	Typhoid Fever.	Measles.	Cerebro-spinal Meningitis.
December,	10	651	924	105	1,072	23
January,	2	739	709	76	2,186	17
February,	-	912	628	86	2,661	34
March,	-	979	737	65	3,474	30
April,	-	795	544	743	3,771	23
May,	2	842	689	337	4,228	11
June,	-	447	589	187	2,249	12
July,	-	237	452	256	797	15
August,	-	331	518	432	209	12
September,	1	409	709	623	106	10
October,	-	662	1,209	441	314	10
November,	1	829	1,231	288	678	8
Totals,	16	7,833	8,939	3,639	21,745	205

The following table is introduced for the purpose of facilitating the comparison of the seasonal prevalence of the diseases named in the table, in different years. By means of the method employed, the errors due to the difference in the length of the months are eliminated. The figures should be read as follows: for example, the mean daily number of reported cases of diphtheria throughout the year, Dec. 1, 1907, to Nov. 30, 1908, was 24.5; of scarlet fever, 21.5; of typhoid fever, 10.0; and of measles, 59.6. During the month of December the mean daily number of reported cases of these diseases was: for diphtheria, 29.8; scarlet fever, 21.0; typhoid fever, 3.4; and for measles, 34.6 (see columns marked A). Assuming a standard of 10 as a daily mean throughout the year for each disease, the ratios for December were as follows: diphtheria, 12.2; scarlet fever, 9.7; typhoid fever, 3.4; and measles, 5.8 (see columns marked B). So that for each 10 cases of diphtheria reported as a daily mean throughout the year, Dec. 1, 1907, to Nov. 30, 1908, there were 12.2 in December, 9.3 in January, 8.9 in February, etc.

From this table it appears that the maximum prevalence of diphtheria was in November and the minimum in July. December and October were also above the mean in intensity of prevalence.

The prevalence of scarlet fever was above the mean in January, February, March, April, May and November, and below it in the remaining months, excepting October, when it stood at the daily mean for the year. The maximum occurred in March and the minimum in July.

Typhoid fever was below the mean in the intensity of its prevalence in the months December, January, February, March, June, July and November, rising to a maximum in April.

The prevalence of measles was above the mean in the months January to June, inclusive, and below it in the remaining months, the maximum occurring in May and the minimum in September.

Certain Infective Diseases. — Seasonal Intensity of Prevalence.

Months.	Diphtheria.			Scarlet Fever.			Typhoid Fever.			Measles.		
	1908.		1907.	1908.		1907.	1908.		1907.	1908.		1907.
	A	B	B	A	B	B	A	B	B	A	B	B
	Mean Daily Number of Cases reported in Each Month.	Decimal Ratio.	Decimal Ratio.	Mean Daily Number of Cases reported in Each Month.	Decimal Ratio.	Decimal Ratio.	Mean Daily Number of Cases reported in Each Month.	Decimal Ratio.	Decimal Ratio.	Mean Daily Number of Cases reported in Each Month.	Decimal Ratio.	Decimal Ratio.
December,[1]	29.8	12.2	18.7	21.0	9.7	8.7	3.4	3.4	8.3	34.6	5.8	5.6
January,	22.9	9.3	13.3	23.8	11.1	22.4	2.5	2.5	5.8	70.5	11.8	5.3
February,	21.7	8.9	10.1	31.4	14.6	15.8	3.0	3.0	5.8	91.8	15.4	6.7
March,	23.8	9.7	9.8	31.6	14.7	13.3	2.1	2.1	4.5	112.1	18.8	11.2
April,	18.1	7.4	10.4	26.5	12.3	11.3	24.8	24.8	4.8	125.7	21.1	18.2
May,	22.2	9.1	8.8	27.2	12.7	7.7	10.9	10.9	3.9	136.4	22.9	16.7
June,	19.6	8.0	9.2	14.9	6.9	3.4	6.2	6.2	5.0	75.0	12.6	20.3
July,	14.6	6.0	6.7	7.6	3.5	5.1	8.3	8.3	7.0	25.7	4.3	8.7
August,	16.7	6.8	7.5	10.7	5.0	4.4	13.9	13.9	13.4	6.7	1.1	4.9
September,	23.6	9.6	8.2	13.6	6.3	6.2	20.8	20.8	26.9	3.5	0.6	2.5
October,	39.0	15.9	10.8	21.4	10.0	7.3	14.2	14.2	22.8	10.1	1.7	3.5
November,	41.0	16.7	11.5	27.6	12.8	10.0	9.6	9.6	12.2	22.6	3.8	16.6
Mean,	24.5	10.0	10.0	21.5	10.0	10.0	10.0	10.0	10.0	59.6	10.0	10.0

[1] The figures for December, in the first two columns, are for 1907, and in the third column, for 1906.

Cases of Infective Diseases reported to the State Board of Health from 296 Cities and Towns, from Nov. 30, 1907, to Nov. 30, 1908.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Abington,	-	5	6	11	6	-	-	8
Acton,	-	110	28	-	4	-	-	-
Acushnet,	-	63	2	1	-	-	-	-
Adams,	51	84	8	3	2	-	-	-
Agawam,	5	-	2	13	1	-	-	-
Amesbury,	11	63	5	9	2	-	-	4
Amherst,	1	-	10	1	-	-	-	-
Andover,	12	-	6	5	4	-	-	-
Arlington,	21	294	26	4	13	1	-	2
Ashburnham,	5	4	-	-	1	-	-	-
Ashby,	-	1	1	-	-	-	-	3
Ashfield,	-	-	-	-	-	1	-	-
Ashland,	-	4	4	-	3	-	-	-
Athol,	29	24	10	2	-	-	-	4
Attleborough,	2	62	33	13	17	1	-	1
Auburn,	3	1	5	1	2	-	-	-
Avon,	-	-	6	2	3	-	-	6
Ayer,	2	7	3	-	-	-	-	-
Barnstable,	5	5	1	1	5	-	-	55
Barre,	1	-	-	1	3	-	-	-
Becket,	3	-	-	-	-	-	-	-
Bedford,	2	-	3	-	-	-	-	12
Belchertown,	3	1	-	-	-	-	-	-
Belmont,	1	108	23	1	-	-	-	-
Berkley,	-	-	1	1	-	-	-	-
Berlin,	1	5	1	2	-	-	-	-
Beverly,	35	205	48	21	16	-	-	27
Billerica,	14	14	4	-	-	-	-	-
Blackstone,	4	2	-	4	-	-	-	-
Bolton,	1	-	-	-	-	-	-	-
Boston,	3,094	5,982	2,658	1,534	2,653	109	1	134
Bourne,	-	12	2	1	2	-	-	2
Boylston,	3	-	9	-	-	-	-	-
Braintree,	82	16	36	2	7	-	-	13
Brewster,	3	7	-	-	1	-	-	-
Bridgewater,	10	69	-	2	44	-	-	-

Cases of Infective Diseases, etc. — Continued.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Brimfield,	3	-	3	-	-	-	-	-
Brockton,	62	209	82	46	98	-	-	12
Brookfield,	-	-	1	-	-	-	-	-
Brookline,	52	121	46	25	33	-	1	-
Burlington,	1	1	-	1	-	-	-	-
Cambridge,	397	1,092	412	82	391	8	-	41
Canton,	6	19	7	1	8	1	-	4
Carlisle,	1	-	-	-	-	-	-	-
Charlemont,	-	1	-	-	-	-	-	-
Charlton,	-	-	6	2	2	-	-	-
Chatham,	-	1	-	1	-	-	-	-
Chelmsford,	9	3	16	2	-	3	-	-
Chelsea,	107	466	78	23	45	2	-	25
Cheshire,	2	16	-	-	-	-	-	-
Chester,	1	-	9	-	-	-	-	-
Chesterfield,	-	1	1	1	1	-	-	-
Chicopee,	44	39	169	9	20	2	-	2
Clarksburg,	-	-	-	1	-	-	-	-
Clinton,	8	22	7	-	6	-	-	-
Colrain,	-	8	7	-	-	-	-	-
Concord,	13	12	3	6	5	-	-	11
Conway,	-	-	3	-	-	-	-	-
Cummington,	-	-	-	-	2	-	-	-
Dalton,	-	-	7	-	-	-	-	-
Danvers,	3	347	13	30	7	1	-	27
Dartmouth,	-	22	5	4	-	-	-	-
Dedham,	12	35	13	3	7	-	-	-
Deerfield,	2	1	-	-	-	-	-	-
Dennis,	2	28	-	-	-	-	-	-
Dighton,	3	8	4	4	-	-	-	-
Douglas,	-	34	-	4	-	-	-	-
Dudley,	3	2	6	2	-	-	-	-
Dunstable,	-	1	1	-	1	-	-	-
Duxbury,	8	1	-	3	-	-	-	-
East Bridgewater,	-	45	3	1	40	1	-	-
East Longmeadow,	1	-	1	3	-	-	-	2
Eastham,	-	-	2	-	-	-	-	-

Cases of Infective Diseases, etc. — Continued.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Easthampton,	10	-	7	5	1	-	-	-
Easton,	-	-	4	-	8	-	-	-
Edgartown,	-	-	-	1	-	-	-	-
Enfield,	-	-	1	1	-	-	-	-
Erving,	2	-	7	-	1	-	-	-
Essex,	1	-	17	1	2	-	-	-
Everett,	94	518	106	76	60	-	-	56
Fairhaven,	1	1	2	1	-	-	-	-
Fall River,	41	51	147	51	88	8	9	27
Falmouth,	8	15	1	8	1	-	-	1
Fitchburg,	88	48	27	41	11	-	-	4
Florida,	-	2	-	1	-	-	-	-
Foxborough,	8	8	5	1	1	-	-	-
Framingham,	1	1	6	6	4	-	-	6
Franklin,	8	16	11	-	-	-	-	-
Freetown,	-	87	1	-	-	-	2	-
Gardner,	22	168	18	11	24	-	-	4
Gay Head,	-	17	-	-	-	-	-	-
Georgetown,	-	-	1	-	1	-	-	-
Gill,	4	-	1	-	-	-	-	-
Gloucester,	85	13	24	12	9	-	-	1
Grafton,	84	-	29	8	-	-	-	-
Granby,	2	-	-	-	1	-	-	-
Great Barrington,	1	65	16	11	8	-	-	-
Greenfield,	5	47	4	2	-	-	-	-
Groveland,	10	31	8	-	-	-	-	-
Hadley,	5	1	1	2	8	-	-	-
Halifax,	-	4	1	-	-	-	-	-
Hamilton,	1	-	1	-	-	-	-	-
Hanover,	1	-	-	-	-	-	-	-
Hanson,	1	-	1	1	-	1	-	-
Hardwick,	16	1	12	1	-	-	-	-
Harvard,	5	2	8	-	-	-	-	-
Harwich,	-	48	5	8	2	-	-	-
Hatfield,	6	1	8	-	1	-	-	15
Haverhill,	171	636	18	44	163	1	-	21
Hingham,	1	-	-	-	-	-	-	-

Cases of Infective Diseases, etc. — Continued.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Hinsdale, ...	-	-	3	-	3	-	-	-
Holbrook, ...	2	-	-	5	1	-	-	-
Holden, ...	8	4	13	4	3	-	-	-
Holliston, ...	4	11	2	-	-	-	-	-
Holyoke, ...	208	85	84	17	85	1	-	1
Hopedale, ...	2	-	6	1	-	-	-	-
Hopkinton, ...	19	3	11	-	3	-	-	-
Hubbardston, . . .	1	3	9	2	-	-	-	-
Hudson, ...	22	8	2	6	1	-	-	-
Hull, ...	1	28	4	6	-	-	-	-
Huntington, ...	2	-	-	1	-	-	-	-
Hyde Park, ...	28	170	47	21	28	2	-	3
Ipswich, ...	4	9	8	3	4	-	-	-
Kingston, ...	-	3	2	1	-	-	-	-
Lakeville, ...	-	5	2	4	1	-	-	-
Lancaster, ...	5	8	4	2	1	-	-	-
Lanesborough, . . .	-	-	6	-	-	-	-	-
Lawrence, ...	152	239	103	111	26	5	1	10
Lee, ...	-	-	1	-	-	-	-	-
Leicester, ...	3	-	1	1	-	-	-	-
Lenox, ...	1	3	-	1	-	-	-	-
Leominster, ...	44	337	17	12	13	-	-	28
Lexington, ...	4	17	2	3	3	-	-	3
Lincoln, ...	-	37	-	-	2	-	-	-
Littleton, ...	-	21	3	-	-	-	-	-
Longmeadow, . . .	4	1	1	-	-	-	-	-
Lowell, ...	309	684	96	181	70	14	1	34
Lunenburg, ...	1	-	-	-	-	-	-	-
Lynn, ...	353	283	202	89	52	2	-	3
Lynnfield, ...	-	5	-	-	-	-	-	-
Malden, ...	132	936	105	45	88	-	-	7
Manchester, ...	-	271	1	1	-	-	-	-
Mansfield, ...	5	20	17	-	2	-	-	55
Marblehead, ...	8	7	2	2	2	-	-	1
Marion, ...	1	3	-	-	-	-	-	-
Marlborough, . . .	12	9	9	5	13	-	-	-
Marshfield, ...	3	-	-	1	-	-	-	-

Cases of Infective Diseases, etc. — Continued.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Mattapoisett, . .	-	69	-	-	-	-	-	-
Maynard, . . .	7	7	-	1	2	-	-	-
Medfield, . . .	4	15	3	2	33	-	-	1
Medford, . . .	67	209	68	15	27	-	-	7
Medway, . . .	5	2	2	1	3	-	-	7
Melrose, . . .	62	362	84	5	3	-	-	2
Mendon, . . .	-	2	6	1	-	-	-	-
Merrimac, . . .	4	34	-	1	-	-	-	-
Methuen, . . .	20	13	8	9	5	1	-	-
Middleborough, . .	4	35	21	1	1	-	-	-
Middlefield, . . .	-	-	1	-	-	-	-	-
Middleton, . . .	9	21	-	-	-	-	-	-
Milford, . . .	15	30	12	4	-	-	-	-
Millbury, . . .	4	4	4	3	-	-	-	8
Millis, ...	6	19	1	-	-	-	-	-
Milton, ...	12	65	18	8	6	1	-	16
Monroe, ...	-	2	-	-	-	-	-	-
Monson, . . .	18	8	8	1	7	-	1	-
Montague, . . .	2	-	1	1	1	-	-	-
Nahant, ...	1	-	5	-	-	-	-	-
Nantucket, . . .	-	-	1	1	-	-	-	-
Natick, ...	4	-	28	-	-	-	-	-
New Bedford, . .	83	528	176	81	123	4	-	48
New Braintree, . .	-	7	-	-	-	-	-	-
New Salem, . . .	-	-	1	-	-	-	-	-
Newbury, . . .	-	-	1	-	-	-	-	-
Newburyport, . .	40	56	23	58	26	1	-	20
Newton, ...	193	482	91	30	65	9	-	32
North Adams, . .	20	746	8	27	26	1	-	-
North Andover, . .	9	12	7	6	1	-	-	3
North Attleborough, .	3	6	11	3	6	1	-	9
North Brookfield, . .	-	38	2	-	-	-	-	-
North Reading, . .	1	4	2	-	2	-	-	-
Northampton, . .	37	233	88	21	34	2	-	69
Northborough, . .	6	2	11	-	-	-	-	-
Northbridge, . . .	37	26	17	3	3	-	-	-
Northfield, . . .	2	9	1	1	1	-	-	-

Cases of Infective Diseases, etc. — Continued.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Norton,	-	2	5	-	-	-	-	-
Norwell,	-	-	-	1	-	1	-	2
Oak Bluffs,	-	1	1	1	-	-	-	-
Orange,	8	8	18	1	-	-	-	-
Orleans,	2	-	1	-	-	-	-	-
Oxford,	-	39	10	5	-	1	-	5
Palmer,	30	23	28	9	8	-	-	-
Paxton,	2	1	1	-	-	-	-	-
Peabody,	16	191	16	21	9	-	-	2
Pembroke,	-	1	-	5	-	-	-	-
Pepperell,	-	4	2	1	-	-	-	-
Petersham,	1	2	3	-	6	-	-	-
Pittsfield,	20	125	47	19	49	-	-	-
Plainville,	-	-	2	-	-	-	-	-
Plymouth,	8	-	9	7	-	-	-	-
Plympton,	-	5	-	-	-	-	-	-
Prescott,	1	-	-	-	-	-	-	-
Princeton,	-	-	-	-	-	-	-	7
Provincetown,	2	3	-	3	4	-	-	-
Quincy,	127	52	68	25	34	2	-	2
Randolph,	5	-	5	5	2	-	-	-
Raynham,	-	-	-	1	-	-	-	-
Reading,	20	197	5	2	-	-	-	-
Rehoboth,	1	-	5	4	-	-	-	-
Revere,	44	-	67	11	4	-	-	-
Rochester,	-	2	-	2	1	-	-	-
Rockland,	1	-	7	5	11	1	-	12
Rockport,	7	33	4	4	12	-	-	13
Rowley,	-	1	8	2	-	-	-	-
Royalston,	-	4	-	-	1	-	-	-
Russell,	-	-	1	3	-	-	-	-
Rutland,	-	-	-	-	338	-	-	-
Salem,	99	646	53	39	64	4	-	34
Salisbury,	1	-	3	3	-	-	-	-
Sandwich,	-	1	-	2	-	-	-	1
Saugus,	12	20	12	-	-	-	-	-
Savoy[illegible]eld,	-	-	-	-	-	-	-	2

Cases of Infective Diseases, etc. — Continued.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Scituate, . . .	-	1	1	-	-	-	-	-
Sharon, ...	2	8	6	1	1	-	-	-
Shelburne, . . .	-	-	-	-	-	1	-	-
Sherborn, . . .	1	-	-	-	-	-	-	-
Shirley, ...	16	-	6	-	-	-	-	-
Shrewsbury, . . .	2	2	2	1	-	-	-	-
Somerset, . . .	-	10	8	2	-	-	-	-
Somerville, . . .	249	500	255	61	120	2	-	11
South Hadley, . .	10	5	6	-	-	1	-	4
Southampton, . .	2	-	-	-	-	-	-	-
Southborough, . .	-	-	-	1	-	-	-	-
Southbridge, . . .	13	-	7	1	-	-	-	-
Southwick, . . .	-	-	-	-	1	-	-	-
Spencer, . . .	4	80	2	8	-	-	-	-
Springfield, . . .	288	75	200	95	81	1	-	13
Sterling, . . .	2	19	2	1	-	-	-	-
Stockbridge, . . .	1	101	9	3	-	-	-	-
Stoneham, . . .	12	17	10	1	1	1	-	-
Stoughton, . . .	7	85	2	1	3	-	-	-
Sturbridge, . . .	-	-	4	-	-	-	-	-
Sudbury, . . .	-	8	1	3	-	-	-	6
Sunderland, . . .	-	18	2	1	-	-	-	-
Sutton, ...	18	2	7	4	1	-	-	11
Swampscott, . . .	5	34	6	3	3	-	-	-
Swansea, . . .	1	4	-	3	1	-	-	-
Taunton, . . .	26	41	80	3	27	1	-	12
Templeton, . . .	33	6	4	3	-	-	-	-
Tisbury, . . .	-	1	3	-	-	-	-	-
Tolland, . . .	3	-	-	-	-	-	-	-
Topsfield, . . .	5	4	-	-	1	-	-	2
Townsend, . . .	1	5	2	2	1	-	-	-
Tyngsborough, . .	-	1	-	-	-	-	-	-
Upton, ...	-	4	1	4	3	-	-	3
Uxbridge, . . .	11	29	4	1	-	-	-	-
Wakefield, . . .	11	137	17	11	3	-	-	-
Walpole, . . .	10	42	7	1	2	-	-	-
Waltham, . . .	131	148	110	28	34	1	-	19

Cases of Infective Diseases, etc. — Concluded.

	Diphtheria.	Measles.	Scarlet Fever.	Typhoid Fever.	Tuberculosis.	Cerebro-spinal Meningitis.	Small-pox.	Whooping Cough.
Ware,	42	-	1	-	7	-	-	-
Wareham,	2	26	11	-	6	-	-	-
Warren,	17	3	1	4	1	-	-	-
Warwick,	1	-	5	-	-	-	-	-
Watertown,	26	43	24	6	5	2	-	1
Wayland,	1	8	-	-	-	-	-	1
Webster,	1	1	7	-	-	1	-	-
Wellesley,	15	15	15	14	4	1	-	12
Wellfleet,	-	-	-	1	-	-	-	-
Wendell,	-	-	1	-	-	-	-	-
Wenham,	2	16	2	1	-	-	-	-
West Boylston,	-	4	23	1	-	-	-	-
West Newbury,	-	1	1	-	-	-	-	-
West Springfield,	51	-	14	1	-	-	-	-
West Stockbridge,	7	-	4	-	-	-	-	-
Westborough,	3	2	3	4	-	-	-	-
Westfield,	3	90	30	31	16	1	-	-
Westford,	2	5	3	-	-	-	-	-
Westhampton,	4	-	-	-	-	-	-	-
Westminster,	-	2	2	1	-	-	-	-
Weston,	-	55	-	-	2	-	-	-
Westport,	1	40	1	1	-	-	-	-
Westwood,	1	5	1	2	-	-	-	-
Weymouth,	42	50	11	11	8	-	-	-
Whately,	1	-	1	-	-	-	-	-
Whitman,	-	11	8	5	5	-	-	-
Wilbraham,	8	-	4	-	-	-	-	-
Williamsburg,	1	41	9	1	-	-	-	5
Williamstown,	2	203	2	1	1	-	-	-
Wilmington,	3	11	-	3	-	-	-	-
Winchendon,	11	7	13	14	2	1	-	4
Winchester,	8	103	117	14	5	-	-	5
Winthrop,	10	46	84	9	7	-	-	18
Woburn,	40	39	62	8	10	1	-	-
Worcester,	698	599	415	105	14	2	-	41
Wrentham,	1	6	2	1	-	-	-	-
Yarmouth,	-	5	4	-	-	-	-	-
Total,	8,939	21,745	7,883	3,639	5,939	205	16	1,134

Actinomycosis occurred in the following places:—

Chelsea,	1
Lynn,	1
	2

Anterior poliomyelitis occurred in the following places:—

Cambridge,	1
Holyoke,	1
North Adams,	1
	3

Anthrax occurred in the following place:—

Lynn,	3

Erysipelas occurred in the following places:—

Chicopee,	1
Dighton,	1
Lynn,	2
Salem,	5
Somerville,	1
Swansea,	2
Watertown,	1
	13

Hydrophobia occurred in the following places:—

Braintree,	3
Newton,	1
	4

Leprosy occurred in the following place:—

Fall River,	1

Malignant pustule occurred in the following place:—

Cambridge,	2

Mumps occurred in the following places:—

Canton,	1
Chelsea,	1
Hyde Park,	8

Melrose,	1
Newton,	3
Northfield,	1
Oxford,	1
Wellesley,	1
West Boylston,	1
	18

Ophthalmia neonatorum occurred in the following places: —

Barnstable,	1
Cambridge,	2
Everett,	1
Haverhill,	1
Lancaster,	1
Lowell,	1
Newburyport,	2
Quincy,	1
Rockland,	1
Salem,	2
Worcester,	3
	16

Scabies occurred in the following place: —

Concord,	2

Tetanus occurred in the following places: —

Attleborough,	1
Chicopee,	1
Fitchburg,	1
Haverhill,	1
Lowell,	1
Milton,	1
Quincy,	1
Springfield,	2
Worcester,	3
	12

Trachoma occurred in the following places: —

Lynn,	1
Worcester,	6
	7

Trichinosis occurred in the following places:—

New Bedford,	1
Somerville,	1
	2

Tubercular meningitis occurred in the following places:—

Chesterfield,	1
Haverhill,	1
Newburyport,	1
Waltham,	2
Worcester,	1
	6

Tuberculosis other than phthisis occurred in the following places:—

Brockton,	1
Gloucester,	1
Haverhill,	1
Hudson,	1
Quincy,	1
	5

Varicella occurred in the following places:—

Abington,	17
Adams,	1
Arlington,	4
Attleborough,	1
Barnstable,	2
Beverly,	9
Billerica,	1
Boston,	125
Braintree,	2
Brockton,	9
Brookline,	6
Cambridge,	66
Canton,	4
Chelsea,	16
Chicopee,	8
Concord,	14
Dana,	1
Dedham,	13
Duxbury,	3
East Bridgewater,	24
Easton,	14
Everett,	65
Fall River,	5
Falmouth,	25
Foxborough,	1
Framingham,	2
Gardner,	14
Gloucester,	7
Great Barrington,	10
Groveland,	3
Hadley,	1
Haverhill,	38
Hudson,	1
Hyde Park,	10
Ipswich,	1
Lawrence,	5
Leominster,	2
Lexington,	1
Lincoln,	4
Lowell,	26
Lynn,	5
Malden,	12
Mansfield,	1
Marlborough,	2

Medford,	1	Springfield,	26
Melrose,	9	Stoughton,	2
Methuen,	16	Taunton,	7
Monson,	1	Templeton,	14
New Bedford,	13	Townsend,	17
Newton,	38	Waltham,	27
North Adams,	8	Wareham,	4
North Attleborough,	1	Watertown,	4
Northampton,	6	Wellesley,	11
Oak Bluffs,	4	Wenham,	6
Oxford,	1	Westfield,	3
Palmer,	2	Whitman,	1
Pembroke,	1	Williamsburg,	8
Pepperell,	1	Williamstown,	12
Pittsfield,	8	Winchendon,	5
Quincy,	3	Winchester,	2
Rockport,	1	Woburn,	1
Salem,	20	Worcester,	23
Savoy,	2		
Somerville,	14		905
Southborough,	1		

List of Cities and Towns from which no Reports were received.

I. Cities.

None.

II. Towns having a Population of More than 5,000.

Norwood, — 1.

III. Towns having a Population of More than 1,000 but Less than 5,000 in Each.

Bellingham,
Buckland,
Carver,
Cohasset,
Dracut,
Groton,
Ludlow,
Needham,
New Marlborough,
Norfolk,
Seekonk,
Sheffield,
Stow,
Tewksbury,
West Bridgewater,
West Brookfield, — 16.

IV. Towns having Less than 1,000 Inhabitants.

Alford,
Bernardston,
Blandford,
Boxborough,
Boxford,
Chilmark,
Dover,
Egremont,
Goshen,
Gosnold,
Granville,
Greenwich,
Hampden,
Hancock,
Hawley,
Heath,
Holland,
Leverett,

III. Towns having less than 1,000 Inhabitants — Concluded.

Leyden.	Pelham.	Truro.
Mashpee.	Peru.	Tyringham.
Monterey.	Phillipston.	Wales.
Montgomery.	Plainfield.	Washington.
Mt. Washington.	Richmond.	West Tisbury.
New Ashford.	Rowe.	Windsor.
Oakham.	Sandisfield.	Worthington. 45.
Otis.	Shutesbury.	

A supply of postal cards for the purpose of reporting infectious diseases to the State Board of Health, as required by statute, will be forwarded to any local board of health on application to the secretary of the State Board, Room 145, State House, Boston.

IV.

Official Returns of Deaths in Cities and Large Towns (Revised Laws, Chapter 75, Section 12).

In the following summary, the statistics of deaths required by chapter 75, section 12, of the Revised Laws, are presented. These statistics are returned to the Board from each city and town which has, "according to the latest census, more than five thousand inhabitants."

The cities and towns which have contributed these returns for the year 1907 comprise practically the same list as that of 1906. This list embraces all of the 33 cities and the towns having more than 5,000 inhabitants in each.

Hingham and Williamstown have again made returns, although their populations fell below 5,000 in 1905.

The list for the year 1907 includes 100 cities and towns. The total estimated population of this group of cities and towns in 1907, based upon the rate of growth between the two census years 1900 and 1905, was 2,672,090, or about 87 per cent. of the estimated total population of the State.

The whole number of registered deaths in these cities and towns in 1907 was 46,671, and the death-rate, as calculated from the foregoing estimated population, was 17.46 per 1,000 of the living population, that of the previous year having been 16.61 per 1,000, and that of 1905, 16.77 per 1,000.

The death-rate for the year 1907 was somewhat higher than that of 1906, but considerably lower than the mean annual death rate of the State for the fifty years ended Dec. 31, 1900, which was 19.22 per 1,000

Sexes. — The number of deaths of males was 23,937, or 51.30 per cent. of the whole number of deaths whose sex was known; and the deaths of females were 22,728, or 48.70 per cent. There were 6 in which the sex was not stated in the returns.

Ages. — The deaths by four groups of ages were as follows: —

Ages.	Deaths 1907.	Percentages of All Deaths.	
		1907.	1906.
Under 1 year,	10,050	21.55	22.06
1 to 20 years,	6,212	13.32	15.80
20 to 50 years,	11,355	24.34	23.96
50 and over,	19,026	40.79	38.18

Infant Mortality. — The deaths of infants under one year old were 10,050, or 21.55 per cent. of the total mortality, as compared with 22.06 per cent. in 1906. In the year 1900 the rate was 23; that of the five years 1903–07, respectively, constituted 21.38, 21.34, 21.27, 22.06 and 21.55 per cent. of the total mortality.

The deaths of children under five years old were 13,377, or 28.7 per cent. of the total mortality, as compared with 31.1 per cent. for the same age in 1906.

All of the percentages in the foregoing table were estimated upon the number of deaths of those whose ages were stated in the returns. The total number of deaths in which the age was not specified was 28; in 1906 it was 40.

Still-births. — The number of still-births was 3,147, and when compared with the total mortality (still-births included), this was 6.3 per cent. of the total deaths and still-births combined. In 1906 the percentage was 7.4.

Months and Quarters. — The number of deaths in each quarter of the year is shown in the following table: —

	Deaths 1907.	Percentages.	
		1907.	1906.
First quarter,	12,338	26.44	25.45
Second quarter,	10,990	23.55	24.09
Third quarter,	12,005	25.72	26.21
Fourth quarter,	11,336	24.29	24.25
Total,	46,669	100.00	100.00

These percentages differ but little from the mean of several years, which usually shows the highest mortality in the third quarter of the year. As in 1899, 1901, 1903 and 1904, the highest mortality was in the first quarter.

During the forty-year period (1856–95) the mortality was generally above the mean in the third quarters of the years and below it in the other three quarters.

The intensity of the seasonal death-rate is more accurately shown in the following table, the method employed being explained on page 795 in Section III. of these summaries, relating to disease notification. By this method the errors which are due to differences in the length of the months are eliminated.

	Deaths in Each Month.	Mean Daily Deaths per Month 1907.	Centesimal Ratio.	
			1907.	1906.
January,	4,257	137.3	107.4	97.2
February,	3,869	138.2	108.1	106.5
March,	4,212	135.9	106.3	106.3
April,	3,945	131.5	118.5	105.1
May,	3,634	117.2	91.7	97.3
June,	3,411	113.7	89.0	87.4
July,	3,605	116.3	91.0	99.5
August,	4,532	146.2	114.4	111.0
September,	3,868	128.9	100.9	101.5
October,	3,630	117.1	91.6	95.5
November,	3,308	110.3	86.3	91.5
December,	4,398	141.9	111.0	101.6
Annual mean,	-	127.8	100.00	100.00

The figures in the foregoing table indicate a departure in excess of the mean death-rate in January, February, March, April, August, September and December, while that of the remaining months was below the mean.

The mean maximum departure from the death-rate for each month for the period of twenty years, 1856–75, was 32.9 per cent. in August, and the twenty-year period 1876–95 it was 20 per cent. in August, while that of August, 1907, was 14 per cent. and those of February and March, 1907, were, respectively, 8.1 and 6.3 per cent.

In the two years having the highest death-rates in Massachusetts in the past half-century or more (1849 and 1872) the maximum departures from the yearly means were, respectively, 83.4 per cent. in August, 1849, and 40 per cent. in August, 1872. That of January, 1890, the month in which the epidemic of influenza was at its maximum, was 43.4 per cent. above the mean.

The figures for 1907, when compared with those of earlier years in the past half-century, show a much greater uniformity in the seasonal

mortality, since serious epidemics have not prevailed in the State either in the past year or in any of the years of the past decade.

Death-rates of Cities and Large Towns. — In Table II., last column, the death-rates of cities and towns having over 5,000 inhabitants are given. These death-rates are obtained by comparing the deaths in each city and town with the estimated population. They vary from a minimum of 9.2 in Wellesley to 22.2 per 1,000 in Fall River.

The following cities and towns had death-rates above 19 per 1,000 in 1907: Fall River, 22.2; Lowell, 21.4; Ipswich, 21.2; Hingham, 20.9; Amesbury, 20.3; Weymouth, 20.3; Chicopee, 20.2; Holyoke, 20.2; Middleborough, 20.1; Blackstone, 20.1; Grafton, 19.7; New Bedford, 19.3; Ware, 19.3; Braintree, 19.3; Milford, 19.2; Stoneham, 19.2; Saugus, 19.1; Plymouth, 19.0; Lawrence, 19.0.

Of the foregoing, Fall River, Hingham, Lowell, Milford and Ware had death-rates above 19 per 1,000 in 1906.

The following cities and towns had death-rates less than 12 per 1,000 in 1907: Hyde Park, 11.9; Reading, 11.9; Winchendon, 11.9; Winchester, 11.3; Concord, 11.1; Bridgewater, 10.8; Brookline, 10.8; Wellesley, 9.2; of these, Bridgewater, Concord, Winchester and Wellesley also had death-rates below 12 per 1,000 in 1906.

The following table presents the mean death-rates of cities over 25,000 population for the seven census years 1870, 1875, 1880, 1885, 1890, 1895 and 1900, together with the death-rates for the years 1905 and 1907: —

Death-rates of Certain Cities having a Population of More than 25,000. Mean Death-rates of the Seven Census Years 1870, 1875, 1880, 1885, 1890, 1895, 1900, and for 1905 and 1907.

	Mean Death-rates, 1870, 1875, 1880, 1885, 1890, 1895 and 1900.	Death-rate, 1905.	Death-rate, 1907.		Mean Death-rates, 1870, 1875, 1880, 1885, 1890, 1895 and 1900.	Death-rate, 1905.	Death-rate, 1907.
Boston,	23.3	18.5	19.2 [1]	Brockton,	15.8	12.7	13.2
Worcester,	19.5	17.4	19.4 [1]	Haverhill,	17.2	15.5	16.5
Fall River,	22.8	20.2	22.2	Salem,	21.4	19.5	18.9
Lowell,	21.8	20.0	21.4	Chelsea,	19.7	18.4	17.6 [1]
Cambridge,	19.0	15.5	15.4	Malden,	16.4	13.3	13.8
Lynn,	17.4	16.2	15.7	Newton,	14.3	13.1	12.2
Lawrence,	21.7	19.6	19.0	Fitchburg,	16.4	13.1	14.8
New Bedford,	20.7	17.2	19.4	Taunton,	19.7	21.8	23.4 [1]
Springfield,	19.0	15.2	16.5	Gloucester,	20.6	14.8	13.8
Somerville,	17.1	14.0	13.7	Quincy,	17.1	13.1	12.9
Holyoke,	22.2	16.3	20.2	Waltham,	15.0	13.7	14.0

[1] These figures for Boston, Chelsea, Worcester and Taunton include all deaths. By exclusion of deaths of non-residents in Boston and deaths in public and private institutions in the other 3 cities, the death-rates would be reduced to 14.5 in Chelsea, 17.2 in Boston, 19.0 in Taunton and 17.9 in Worcester.

Causes of Death. — In Table III. the mortality of the cities and towns embraced in this summary is presented in absolute figures, classified ac-

cording to the principal causes of death. The same figures are again presented in relative terms in Table IV., for the whole group of cities and towns combined. Two sets of figures are given in Table IV., in one of which the mortality from each principal cause of death is compared with the estimated population of the group for 1907, as well as for each of the last five years, and in the other with the total mortality of the group of cities and towns.

By this it appears that the general death-rate from all causes, as shown in the lower line at the left of the table, 174.65 per 10,000 living, or, as usually stated, 17.46 per 1,000, was higher than that of any year since 1900, when the rate was 18.26. In the years 1906, 1905, 1904 and 1903, it was 16.61, 16.77, 15.46, 16.13 and 16.20 respectively. The population comprised in these returns constitutes about 87 per cent. of that of the whole State.

While there has been an increase in the general death-rate during the year 1907, there has also been a considerable decrease in the relative number of deaths from infectious diseases, more especially from those which are usually considered preventable.

The death-rate from each of the following causes was less than that of 1906: measles, typhoid fever and whooping cough. Those of measles and dysentery were also less than the death-rates from the same causes in any of the last five years.

The following table, first published in the report of 1899, presents the combined death-rate from eight of the principal infectious diseases, and also shows that this combined death-rate in 1907 was less, with the exception of 1904, than that of any of the years embraced in this series of reports.

The diseases referred to are consumption, measles, scarlet fever, diphtheria, whooping cough, typhoid fever, puerperal fever and cholera infantum.

The combined death-rate per 10,000 of the population from these eight causes for the thirteen years (1895–1907) in the cities and towns included in this report (about six-sevenths of the total population of the State) was as follows: —

Combined Death-rate from Eight Principal Infective Diseases.

YEAR.	Combined Death-rate per 10,000.	YEAR.	Combined Death-rate per 10,000.
1895,	46.4	1902,	30.9
1896,	46.8	1903,	30.7
1897,	39.7	1904,	27.0
1898,	36.3	1905,	28.0
1899,	35.2	1906,	27.9
1900,	40.7	1907,	27.8
1901,	33.5		

With the exception of the year 1906, the death-rate from consumption was lower in 1907 than in any year of record, being 15.50, as against 16.01 in 1905, 16.05 in 1904, 15.66 in 1903 and 16.38 in 1902. In 1906 the death-rate from consumption was 15.11.

The seasonal table which appeared in the earlier reports, presenting the deaths by months for each city and town and for the whole State, is omitted in the present report, since the details presented in this table are not of essential value. Its chief value consisted in the column of total figures for the State, which is retained essentially in the table on page 810.

The table of percentages of total mortality shown in Table IV. acts in a measure as a check or control in case of erroneous estimates of population.

The changes in the death-rate from consumption, typhoid fever and puerperal fever (see child-birth in report of 1896, page 804) were quite fully treated in the report of 1896. To these may be added the later comments on the changes in the death-rate from diphtheria, which appear in the figures of the past thirteen years.

The following preventable causes of death, consumption, measles, scarlet fever, diphtheria, whooping cough, typhoid fever, puerperal fever and cholera infantum, together constituted 27.2 per cent. of the total mortality in 1894, but had fallen off to 24.2, 24.2, 21.9, 21.1, 20.4, 22.3, 19.9, 19, 19, 17.5, 16.7, 16.8 and 15.9 in the thirteen succeeding years; while the principal acute lung diseases, diseases of the heart, brain, kidneys, cancer, suicide and accident had increased from 35.7 per cent. of the total mortality to 36.9, 36.9, 38.5, 39.2, 40.2, 38.6, 40.1, 42.7, 43, 45.7, 46.6, 45.6 and 46.3 in the same years.

These all combined constituted the greater part of the total mortality in each of the fourteen years 1894–1907, and of the diseases specified in the table entitled the "Balance of Mortality," in the annual report of 1896, page 812.

TABLE I.

Population of Cities and Large Towns estimated for 1907.

REPORTING CITIES AND TOWNS.	Estimated Population for 1907.	REPORTING CITIES AND TOWNS.	Estimated Population for 1907.
Abington,	5,317	Blackstone,	5,812
Adams,	13,072	Boston,	609,762
Amesbury,	8,840	Braintree,	7,257
Amherst,	5,427	Bridgewater,	7,132
Andover,	6,632	Brockton,	51,289
Arlington,	10,094	Brookline,	25,008
Athol,	7,251	Cambridge,	99,745
Attleborough,	13,294	Chelsea,	38,659
Beverly,	15,794	Chicopee,	20,615

TABLE I. — *Concluded.*

Reporting Cities and Towns.	Estimated Population for 1907.	Reporting Cities and Towns.	Estimated Population for 1907.
Clinton,	13,105	North Attleborough,	8,128
Concord,	5,421	Northbridge,	7,546
Danvers,	9,271	Norwood,	7,231
Dedham,	7,900	Orange,	5,602
Easthampton,	7,290	Palmer,	7,755
Everett,	31,274	Peabody,	13,787
Fall River,	106,123	Pittsfield,	28,425
Fitchburg,	33,636	Plymouth,	11,796
Framingham,	11,648	Quincy,	29,944
Franklin,	5,834	Reading,	5,968
Gardner,	12,528	Revere,	13,697
Gloucester,	26,011	Rockland,	6,671
Grafton,	5,124	Salem,	38,316
Great Barrington,	6,270	Saugus,	6,721
Greenfield,	9,648	Somerville,	72,581
Haverhill,	38,095	Southbridge,	11,416
Hingham,	4,819	South Hadley,	5,266
Holyoke,	51,730	Spencer,	7,121
Hudson,	6,523	Springfield,	78,707
Hyde Park,	15,050	Stoneham,	6,886
Ipswich,	5,423	Stoughton,	6,165
Lawrence,	76,000	Swampscott,	5,379
Leominster,	15,139	Taunton,	30,967
Lowell,	96,380	Wakefield,	10,687
Lynn,	80,743	Waltham,	27,493
Malden,	39,941	Ware,	8,726
Marblehead,	7,209	Watertown,	11,946
Marlborough,	14,263	Webster,	10,549
Maynard,	6,479	Wellesley,	6,635
Medford,	20,294	Westborough,	5,378
Melrose,	14,867	Westfield,	14,169
Methuen,	9,142	West Springfield,	8,499
Middleborough,	6,888	Weymouth,	11,691
Milford,	12,409	Whitman,	6,667
Milton,	7,244	Williamstown,	4,425
Montague,	7,361	Winchendon,	6,305
Natick,	9,657	Winchester,	8,640
New Bedford,	79,744	Winthrop,	7,424
Newburyport,	14,755	Woburn,	14,462
Newton,	38,209	Worcester,	132,240
North Adams,	22,150		
Northampton,	20,508	Total,	2,672,090

The death-rate of Amesbury, Andover, Clinton, Concord, Gloucester, Hingham, Marblehead, Middleborough, North Adams, Palmer, Spencer, Taunton, Westborough and Williamstown was based on the population of 1905, these cities and towns having slightly decreased in population in the five years which elapsed between the census of 1900 and that of 1905.

While Lowell had fallen off between the two census years, it has, since 1905, made a gain by the annexation of a part of the town of Tewksbury, and this increase is included in the population given above.

TABLE II.

Total Deaths, Deaths by Sexes, and Age Periods and Still-births in Cities and Towns having over 5,000 Inhabitants in Each with General Death-rates estimated for 1907.

	Total Deaths.	Males.	Females.	Sex Unknown.	Still-births.	Deaths under 1.	1-2.	2-3.	3-4.	4-5.	5-10.	10-15.	15-20.	20-30.	30-40.	40-50.	50-60.	60-70.	70-80.	Over 80.	Age Unknown.	Rate per 1,000.
Abington, ...	94	45	49	-	8	14	6	1	1	-	4	1	1	5	5	9	5	12	18	12	-	17.68
Adams, ...	198	101	97	-	10	79	11	4	4	2	6	3	1	7	10	8	16	18	20	8	1	15.15
Amesbury, . . .	180	92	88	-	5	28	6	-	3	1	3	2	9	7	8	14	21	25	30	23	-	20.36
Amherst, ...	79	38	41	-	2	5	1	-	-	-	1	2	1	6	7	5	13	11	14	13	-	14.56
Andover, ...	112	64	48	-	3	9	1	-	1	-	2	1	4	5	11	7	13	16	26	14	2	16.88
Arlington, ...	167	87	80	-	13	22	3	1	1	2	6	3	1	15	14	15	16	27	23	18	-	16.55
Athol, ...	126	52	74	-	4	12	5	1	-	1	2	3	1	9	8	4	11	22	29	16	2	17.38
Attleborough, . .	193	102	91	-	20	46	6	1	-	2	5	3	4	20	7	16	16	24	27	16	-	14.52
Beverly, ...	246	136	110	-	29	27	4	3	1	2	6	3	7	19	25	14	32	35	39	29	-	15.58
Blackstone, . . .	117	64	53	-	6	24	7	2	2	1	3	1	2	10	12	6	7	16	14	10	-	20.13
Boston,[1]	11,686	6,187	5,499	-	732	2,350	425	156	120	109	253	193	247	953	1,326	1,348	1,299	1,341	1,018	548	-	17.17[2]
Braintree, ...	140	66	74	-	10	21	4	-	3	-	-	2	5	6	9	12	16	23	23	14	2	19.35
Bridgewater,[3] . .	77	36	41	-	-	8	-	-	3	-	5	-	3	2	7	7	10	10	12	10	-	10.80[2]
Brockton, ...	676	320	356	-	60	143	20	7	10	5	17	11	18	55	61	54	61	79	77	56	2	13.18
Brookline, ...	272	112	160	-	17	23	2	1	2	-	1	3	4	12	21	25	30	50	60	38	-	10.80
Cambridge, . . .	1,533	756	777	-	94	333	50	18	17	14	40	23	35	117	144	129	123	203	167	111	-	15.37
Chelsea,[4]	679	415	264	-	51	150	19	12	10	4	22	11	18	39	43	88	64	112	95	42	-	14.46[2]
Chicopee, ...	417	238	179	-	24	154	42	19	11	9	10	2	11	15	25	20	26	37	25	11	-	20.22
Clinton, ...	209	99	110	-	10	53	-	2	2	1	5	-	8	20	13	17	18	29	26	15	-	15.94
Concord, ...	60	27	33	-	3	3	1	1	2	-	3	2	5	1	7	4	5	8	11	7	-	11.07
Danvers,[5]	128	61	67	-	8	21	1	2	-	1	2	2	2	6	11	7	6	21	32	14	-	13.81[2]
Dedham, ...	146	68	78	-	6	34	4	2	-	1	2	3	3	9	6	11	15	21	19	15	1	18.48
Easthampton, . . .	115	61	54	-	8	24	-	3	-	2	5	-	5	5	4	8	14	12	19	14	-	15.77

Everett,	410	207	203	-	28	88	13	10	3	3	19	7	7	29	21	39	46	48	48	29	-	13.11
Fall River,	2,359	1,229	1,130	-	185	891	150	88	60	44	97	60	41	165	164	132	185	159	80	43	-	22.23
Fitchburg,	498	243	255	-	55	116	15	8	3	3	6	8	13	30	38	39	48	54	67	41	-	14.80
Framingham,	199	97	102	-	6	37	8	5	1	-	2	4	2	17	9	19	21	28	25	21	-	17.08
Franklin,	74	40	34	-	5	8	2	3	1	-	1	2	1	3	4	1	10	13	14	10	1	13.88
Gardner,	209	116	93	-	13	51	10	8	8	7	9	4	2	21	13	8	13	25	18	11	1	16.61
Gloucester,	360	170	190	-	27	57	5	4	5	-	11	7	11	25	34	30	51	43	44	32	1	13.84
Grafton,	101	44	57	-	8	13	-	2	-	-	1	3	1	7	7	12	13	10	15	17	-	19.71
Great Barrington,	84	48	36	-	5	13	-	-	-	-	1	1	-	7	3	6	9	14	19	11	-	13.40
Greenfield,	124	63	61	-	9	18	6	1	1	-	2	1	3	8	13	8	10	17	20	16	-	12.85
Haverhill,	627	327	300	-	67	81	20	5	12	2	16	9	15	36	50	53	72	96	100	60	-	16.46
Hingham,	101	48	53	-	2	9	4	2	1	2	1	-	1	3	3	4	10	17	27	17	-	20.95
Holyoke,	1,046	545	501	-	94	327	53	41	20	15	34	13	25	77	79	91	77	90	59	45	-	20.22
Hudson,	93	44	49	-	3	10	1	2	1	-	1	-	-	5	10	5	6	16	21	15	-	14.26
Hyde Park,	180	98	81	1	21	33	1	1	6	2	5	7	1	10	20	13	14	24	25	18	-	11.96
Ipswich,	115	60	55	-	9	30	-	2	1	2	-	1	2	6	6	9	11	15	16	14	-	21.21
Lawrence,	1,446	708	738	-	127	401	77	44	11	17	31	27	29	104	137	99	130	160	113	64	2	19.03
Leominster,	256	119	136	1	18	47	10	2	4	3	5	3	10	17	19	16	23	33	38	26	-	16.91
Lowell,	2,063	1,006	1,057	-	157	537	84	45	20	13	45	26	45	135	187	179	215	249	176	107	-	21.40
Lynn,	1,268	698	570	-	119	240	37	16	14	15	39	15	34	84	116	114	145	158	150	91	-	15.70
Malden,	551	258	293	-	20	108	16	10	8	4	17	11	14	27	54	30	49	75	82	46	-	13.80
Marblehead,	120	62	58	-	6	9	2	-	1	3	3	1	-	4	8	8	10	20	33	18	-	16.65
Marlborough,	192	96	96	-	4	29	6	2	4	1	1	1	5	20	8	21	21	24	33	16	-	13.46
Maynard,	106	65	41	-	11	39	7	-	-	1	3	3	5	10	5	6	6	9	6	6	-	16.36
Medford,	272	123	149	-	23	36	2	2	2	-	2	4	8	22	16	18	19	48	60	33	-	13.41
Melrose,	223	96	127	-	13	38	-	2	2	2	6	3	8	15	16	19	24	32	33	22	1	15.00
Methuen,	165	77	88	-	5	28	1	3	1	1	3	2	3	10	14	11	16	24	30	17	1	18.06
Middleborough,	139	66	73	-	-	18	3	3	-	2	6	2	-	3	6	7	12	23	25	29	-	20.18
Milford,	239	117	122	-	11	58	7	3	2	-	8	8	7	16	17	24	23	28	20	18	-	19.26
Milton,	91	47	44	-	6	8	3	-	-	-	1	2	3	3	7	11	9	15	12	17	-	12.56

[1] Non-residents, 1,214, included. [2] In obtaining this death-rate, deaths occurring in public institutions were not included, many being non-residents.
[3] State Farm, 98, additional. [4] Soldiers' Home and Marine and Naval Hospitals, 120, included. [5] Insane Asylum, 170, not included.

TABLE II. — *Concluded.*

	Total Deaths.	Males.	Females.	Sex Unknown.	Still-births.	Deaths under 1.	1-2.	2-3.	3-4.	4-5.	5-10.	10-15.	15-20.	20-30.	30-40.	40-50.	50-60.	60-70.	70-80.	Over 80.	Age Unknown.	Rate per 1,000.
Montague,	134	79	53	2	13	35	1	2	-	1	4	1	-	11	7	8	18	21	18	7	-	18.21
Natick,	149	78	71	-	10	21	2	1	-	2	-	1	4	6	14	10	19	28	25	16	-	15.43
New Bedford,	1,546	792	754	-	139	535	76	22	17	7	32	17	36	94	91	114	122	166	114	102	1	19.39
Newburyport,	270	137	133	-	5	28	4	4	-	3	10	8	6	14	16	20	23	41	57	36	-	18.29
Newton,	467	233	234	-	34	71	11	5	1	2	7	8	18	23	44	34	49	67	80	47	-	12.22
North Adams,	350	174	176	-	15	58	16	4	2	3	11	5	11	34	40	26	36	41	38	25	-	15.80
Northampton,[1]	408	216	192	-	14	47	12	7	2	2	4	6	9	21	38	33	44	64	72	47	-	15.99[2]
North Attleborough,	129	62	67	-	11	28	6	2	2	2	1	-	-	11	7	11	11	17	21	10	-	15.87
Northbridge,	118	56	62	-	10	27	9	3	2	1	2	2	3	6	8	9	12	20	8	6	-	15.64
Norwood,	101	50	51	-	6	24	6	1	-	2	2	1	4	8	5	6	7	9	17	7	2	13.97
Orange,	73	31	42	-	-	13	1	-	-	-	3	-	-	7	2	1	6	12	14	14	-	13.03
Palmer,	135	73	62	-	3	48	7	3	2	-	-	-	3	7	9	4	14	12	16	9	1	17.41
Peabody,	219	122	97	-	10	47	4	1	-	3	4	1	11	12	15	13	26	42	23	17	-	15.88
Pittsfield,	458	237	221	-	23	75	14	3	5	1	10	6	12	38	34	46	52	60	61	40	1	17.33
Plymouth,	225	126	99	-	12	42	8	1	3	-	7	3	5	7	12	20	16	39	38	24	-	19.07
Quincy,	387	214	173	-	32	92	13	3	6	2	8	5	12	25	24	41	32	58	44	22	-	12.93
Reading,	71	28	43	-	6	6	1	-	1	-	2	-	-	5	5	3	6	12	15	15	-	11.90
Revere,	246	130	116	-	10	57	3	3	1	4	10	6	7	21	24	28	22	31	19	10	-	17.96
Rockland,	98	48	50	-	4	7	3	-	1	1	1	-	4	10	7	7	12	15	22	8	-	14.69
Salem,	724	352	370	2	48	183	27	5	8	5	12	10	15	37	53	52	70	102	86	55	4	18.89
Saugus,	129	70	59	-	6	36	5	5	-	1	5	3	1	2	8	8	11	9	18	17	-	19.19
Somerville,	997	455	542	-	75	166	17	12	9	9	25	16	15	66	55	75	111	152	165	104	-	13.74
Southbridge,	193	100	93	-	10	60	11	3	2	2	3	2	7	8	13	13	15	21	22	11	-	16.90
South Hadley,	75	38	37	-	3	21	2	-	-	1	-	1	-	6	5	7	7	12	9	4	-	14.24
[illegible],	108	61	47	-	4	10	1	-	1	-	1	1	2	10	10	5	18	22	15	12	-	15.17

Springfield, . .	1,302	633	669	-	63	233	46	23	9	6	30	23	35	97	128	97	124	170	175	106	-	16.54
Stoneham, . .	123	56	67	-	7	8	1	1	1	-	2	2	2	7	9	8	12	25	27	18	-	19.26
Stoughton, . .	106	56	50	-	6	28	3	-	1	1	2	-	5	10	5	3	9	11	12	16	-	17.19
Swampscott, . .	96	50	46	-	12	9	-	1	-	1	1	-	1	6	6	12	8	18	18	15	-	17.85
Taunton,[3] . . .	725	380	345	-	47	128	19	5	5	4	15	11	14	51	56	69	83	91	114	60	-	18.99[2]
Wakefield, . .	144	69	75	-	11	22	3	2	-	2	-	3	6	8	4	8	20	18	26	22	-	13.47
Waltham, . . .	386	184	202	-	13	52	10	4	3	5	10	11	10	33	37	26	45	48	52	40	-	14.04
Ware, . . .	169	85	84	-	8	51	13	3	2	-	3	4	5	10	10	12	8	20	18	10	-	19.37
Watertown, . .	181	100	81	-	19	33	10	5	1	-	5	6	3	15	16	15	22	21	16	13	-	15.15
Webster, . . .	157	86	71	-	20	42	5	2	1	-	5	1	4	8	11	11	13	23	20	10	1	14.88
Wellesley, . . .	61	29	32	-	4	9	1	1	1	-	2	-	-	4	2	2	4	13	10	12	-	9.19
Westborough,[1] . .	197	88	109	-	-	6	-	1	1	1	2	-	-	8	19	32	27	41	29	30	-	13.76[2]
Westfield, . . .	231	121	110	-	14	48	6	4	2	2	4	5	4	14	7	17	24	30	36	28	-	16.30
West Springfield, .	125	68	57	-	6	30	5	4	-	2	3	5	2	10	8	4	9	18	17	8	-	14.71
Weymouth, . .	237	127	110	-	19	27	3	1	1	1	3	1	1	13	11	16	29	52	46	32	-	20.27
Whitman, . . .	81	48	33	-	6	8	4	-	1	1	1	2	-	1	6	8	12	12	15	10	-	12.15
Williamstown, . .	61	25	36	-	3	8	2	1	-	-	-	-	1	5	5	2	9	16	5	7	-	13.79
Winchendon, . .	75	42	33	-	6	16	4	1	-	1	2	-	2	-	2	5	7	11	14	9	1	11.90
Winchester, . .	98	50	48	-	8	9	8	-	1	1	-	4	-	3	11	9	13	12	16	11	-	11.34
Winthrop, . . .	109	48	61	-	11	9	2	-	-	1	2	3	1	9	11	6	11	14	22	18	-	14.68
Woburn, . . .	264	115	149	-	21	50	9	4	2	2	3	4	4	21	24	21	29	30	27	34	-	18.26
Worcester[5] . .	2,572	1,371	1,201	-	160	526	70	46	36	22	85	22	67	184	227	262	273	297	259	196	-	17.92[2]
	46,671	23,937	22,728	6	3,147	10,050	1,654	749	518	406	1,123	719	1,043	3,277	4,029	4,049	4,685	5,783	5,224	3,334	28	17.46

[1] State Hospital, 80, included. [2] In obtaining this death-rate, deaths occurring in public institutions were not included, many being non-residents.
[3] Insane Asylum, 137, included. [4] Insane Asylum, 123, included. [5] Insane Hospital and Insane Asylum, 202, included.

TABLE III.

Deaths from Specified Causes in Cities and Towns having more than 5,000 Inhabitants in Each, 1907.

	Consumption.	Smallpox.	Measles.	Scarlet Fever.	Diphtheria and Croup.	Whooping Cough.	Typhoid Fever.	Cerebro-spinal Meningitis.	Erysipelas.	Puerperal Fever.	Influenza.	Malarial Fever.	Cholera Infantum.	Dysentery.	Diarrhœa and Cholera Morbus.	Pneumonia.	Bronchitis.	Diseases of the Heart.	Diseases of the Brain and Spinal Cord.	Diseases of the Kidneys.	Cancer.	Suicide.	Accident.	Unknown or Ill-defined Causes.	All Other Causes.
Abington, . .	6	-	-	-	2	-	1	2	1	-	-	1	2	14	-	6	3	12	10	6	3	1	5	-	18
Adams, . .	12	-	-	-	7	-	5	4	1	-	10	-	24	-	3	12	2	19	3	3	8	2	5	-	78
Amesbury, . .	20	-	-	-	4	-	3	-	-	2	2	-	-	-	5	25	3	16	26	19	14	-	11	4	26
Amherst, . .	5	-	-	1	-	-	2	1	-	-	-	-	-	1	-	11	3	14	12	8	3	1	3	7	7
Andover, . .	16	-	-	-	-	-	-	1	-	-	1	-	1	-	2	9	1	13	11	-	8	-	11	-	38
Arlington, . .	15	-	-	-	1	-	2	3	-	-	-	-	1	-	1	15	4	20	10	17	9	-	6	-	63
Athol, . .	14	-	-	1	-	-	-	1	2	-	1	-	2	-	1	18	2	13	22	10	8	-	3	1	27
Attleborough, .	20	-	-	-	-	1	-	3	-	1	2	1	15	2	-	12	4	23	16	9	10	1	3	-	70
Beverly, . .	24	-	-	1	3	1	5	1	1	-	-	-	3	-	-	25	1	35	15	21	20	3	14	-	73
Blackstone, . .	11	-	-	-	2	-	1	-	-	1	1	-	5	-	8	15	3	23	19	10	2	-	6	10	-
Boston, . .	1,122	-	29	49	144	43	64	169	45	25	93	2	130	20	560	1,233	261	1,211	734	643	621	125	684	125	3,516
Braintree, . .	8	-	-	-	-	-	1	5	-	-	4	-	7	1	-	11	4	22	15	5	6	-	7	1	43
Bridgewater, .	6	-	-	1	2	-	-	3	-	-	-	-	-	-	1	7	3	17	5	6	5	1	2	8	10
Brockton, . .	50	-	-	2	8	1	6	2	-	11	2	1	14	2	2	60	5	80	65	34	41	10	25	-	254
Brookline, . .	17	-	-	2	2	1	1	1	1	-	6	-	-	1	1	31	14	55	23	14	29	3	3	-	67
Cambridge, . .	169	-	8	10	19	10	10	16	3	4	25	-	30	4	60	139	47	181	182	92	77	14	63	78	292
Chelsea, . .	59	-	4	3	12	2	2	4	-	-	-	-	27	1	13	56	16	64	81	44	33	5	21	-	232
Chicopee, . .	30	-	1	21	6	3	1	-	1	-	1	-	26	-	11	57	14	20	10	14	12	1	11	4	173
Clinton, . .	12	-	1	-	1	1	7	-	1	-	2	-	-	1	3	13	13	10	1	9	7	-	9	-	118
Concord, . .	5	-	1	2	-	1	1	2	-	-	4	-	-	2	-	2	4	11	5	-	3	-	6	-	11
Danvers, . .	13	-	-	-	1	-	-	6	-	-	-	-	2	-	2	11	2	28	-	8	7	-	3	-	45
Dedham, . .	17	-	1	-	4	4	-	4	-	-	2	1	2	1	12	19	4	16	24	3	8	1	3	-	20
Easthampton, .	11	-	2	-	1	-	1	-	3	-	1	-	3	-	-	18	6	23	1	2	2	3	8	12	17
Everett, . .	33	-	1	5	8	2	3	5	1	-	10	-	14	1	-	44	8	63	3	9	20	3	13	1	163

Fall River, . .	267	3	7	7	38	9	11	9	6	5	16	-	828	8	26	160	87	106	290	84	78	3	51	14	746
Fitchburg, . .	45	-	8	-	3	1	4	-	2	-	2	-	12	2	-	56	13	58	3	20	27	10	18	6	213
Framingham, .	6	-	-	2	1	1	1	2	-	1	-	-	7	-	1	17	3	29	21	10	6	-	18	-	72
Franklin, . .	5	-	-	-	2	-	-	5	-	-	-	-	-	1	1	4	4	7	1	6	-	-	3	-	35
Gardner, . .	13	-	-	28	2	2	3	1	-	1	2	-	6	-	2	15	2	19	21	13	5	-	4	-	69
Gloucester, . .	18	-	-	-	8	-	-	3	2	-	1	-	7	1	-	34	8	25	16	20	19	6	17	-	175
Grafton, . .	15	-	-	-	2	-	1	-	-	1	-	-	4	1	1	9	1	9	-	2	4	2	1	-	48
Great Barrington, .	8	-	-	-	1	3	-	-	-	-	-	-	2	-	-	8	1	13	14	5	6	2	1	-	20
Greenfield, . .	2	-	-	1	-	-	1	7	-	-	2	-	2	-	-	15	-	13	9	3	4	-	8	14	43
Haverhill, . .	65	-	4	6	11	8	9	5	2	-	16	1	11	2	-	89	14	84	45	30	26	11	31	-	157
Hingham, . .	1	-	-	1	2	-	-	3	-	-	-	1	-	-	2	12	4	22	9	8	3	-	4	-	29
Holyoke, . .	91	-	2	16	31	2	3	6	1	4	7	-	38	1	60	148	27	76	66	65	33	4	43	-	321
Hudson, . .	5	-	-	-	3	-	-	-	-	1	2	-	-	-	-	15	5	21	16	6	4	1	-	-	14
Hyde Park, . .	21	-	-	3	3	1	1	3	1	-	1	-	4	-	-	22	1	19	7	12	9	1	13	1	56
Ipswich, . .	6	-	-	-	2	2	1	-	-	-	2	-	2	-	5	9	-	22	9	6	8	-	2	6	33
Lawrence, . .	142	-	12	5	24	9	23	4	2	12	6	-	107	6	13	149	33	111	83	75	56	18	57	107	390
Leominster, . .	20	-	-	1	8	2	2	1	1	-	-	-	4	-	1	31	2	25	28	20	23	1	6	-	79
Lowell, . .	170	-	5	5	45	9	9	20	5	2	8	2	93	7	148	211	89	205	254	113	76	9	80	12	486
Lynn, . . .	113	-	12	12	22	4	12	5	7	2	9	-	34	1	12	143	23	121	122	82	63	11	57	14	383
Malden, . .	45	-	-	2	7	1	7	-	-	-	2	1	19	4	-	67	12	77	76	23	18	2	8	-	179
Marblehead, . .	3	-	-	-	6	6	-	-	-	-	-	-	-	-	-	6	3	20	9	9	5	2	2	-	49
Marlborough, .	17	-	-	-	1	2	-	1	-	-	-	-	4	-	2	16	6	19	29	8	4	-	6	3	74
Maynard, . .	11	-	-	-	-	-	1	1	-	1	1	-	9	1	-	8	2	8	7	3	4	-	8	-	41
Medford, . .	16	-	-	2	3	-	2	2	-	-	1	-	2	-	-	35	4	43	-	17	23	1	8	-	112
Melrose, . .	23	-	-	1	3	2	1	1	-	-	3	-	-	2	7	21	6	39	31	9	15	2	6	1	50
Methuen, . .	10	-	-	-	-	-	2	5	-	2	5	-	5	-	-	13	4	15	17	1	5	-	7	-	74
Middleborough, .	5	-	-	-	-	2	1	1	-	-	4	-	2	2	-	16	2	25	16	1	4	-	1	2	55
Milford, . .	24	-	-	-	2	1	2	10	1	2	1	-	6	1	-	28	-	33	13	17	9	3	5	-	81
Milton, . .	7	-	-	-	1	1	-	-	-	-	-	-	-	-	-	9	-	5	1	4	2	1	-	-	60
Montague, . .	7	-	-	2	2	-	1	3	-	-	3	-	5	2	2	14	5	17	4	6	1	1	3	-	56
Natick, . .	12	-	-	-	1	-	-	-	-	-	7	5	1	-	-	11	6	34	14	14	3	-	6	-	35
New Bedford, .	133	-	-	-	12	3	10	20	6	1	5	-	81	2	2	139	76	163	74	64	44	6	2	1	701
Newburyport, .	22	-	-	2	4	-	2	4	-	-	2	-	1	1	2	31	5	29	-	4	26	-	8	-	127

TABLE III. — *Concluded.*

	Consumption.	Smallpox.	Measles.	Scarlet Fever.	Diphtheria and Croup.	Whooping Cough.	Typhoid Fever.	Cerebro-spinal Meningitis.	Erysipelas.	Puerperal Fever.	Influenza.	Malarial Fever.	Cholera Infantum.	Dysentery.	Diarrhœa and Cholera Morbus.	Pneumonia.	Bronchitis.	Diseases of the Heart.	Diseases of the Brain and Spinal Cord.	Diseases of the Kidneys.	Cancer.	Suicide.	Accident.	Unknown or Ill-defined Causes.	All Other Causes.
Newton,	26	-	-	3	6	1	1	6	-	1	6	-	17	2	5	47	9	49	55	19	26	2	15	-	171
North Adams,	32	-	-	-	5	3	8	3	1	1	1	1	5	6	1	36	6	30	12	3	19	5	20	-	152
Northampton,	30	-	1	1	6	-	6	2	1	-	9	-	5	-	5	27	6	44	76	20	18	4	15	10	122
North Attleborough,	13	-	-	-	1	1	1	2	-	-	-	-	6	-	2	11	3	14	15	5	10	1	-	4	40
Northbridge,	10	-	1	-	7	3	-	3	1	-	1	-	3	-	-	17	4	15	-	10	2	1	5	-	35
Norwood,	6	-	-	4	1	-	-	-	-	-	1	-	7	-	1	11	2	10	4	5	6	1	4	3	35
Orange,	1	-	-	1	-	2	1	1	-	-	1	-	-	-	3	8	2	10	16	4	-	1	1	-	21
Palmer,	15	-	3	-	7	5	-	-	-	-	-	-	6	-	12	14	1	16	18	10	6	2	5	2	13
Peabody,	21	-	1	-	2	-	1	8	-	-	-	-	7	-	1	19	9	26	14	16	14	3	11	1	65
Pittsfield,	37	1	2	2	1	-	2	14	-	-	-	-	3	-	20	55	5	70	44	34	26	2	47	-	93
Plymouth,	17	-	2	-	6	-	2	7	-	-	2	1	5	2	5	12	5	43	17	11	11	1	9	-	66
Quincy,	39	-	1	3	6	-	-	3	1	3	3	-	16	-	33	45	6	55	44	23	19	3	15	-	69
Reading,	8	-	-	-	2	-	1	1	-	-	-	-	-	-	-	7	2	8	9	3	3	1	2	-	24
Revere,	31	-	-	1	6	3	2	6	1	-	-	-	3	1	3	34	1	19	20	11	14	1	10	-	79
Rockland,	9	-	-	-	-	-	-	-	-	1	-	-	6	3	1	13	2	12	2	5	13	-	4	-	27
Salem,	61	-	3	-	11	6	10	4	3	-	3	-	23	1	8	49	21	79	39	43	33	4	28	-	295
Saugus,	8	-	-	-	2	-	-	1	-	-	-	-	3	1	3	16	5	18	-	4	3	-	8	-	57
Somerville,	86	-	2	12	9	2	11	4	4	-	24	-	9	5	3	119	22	113	83	98	67	4	35	-	284
Southbridge,	21	-	2	-	3	6	1	2	-	2	-	-	11	1	10	9	16	13	12	3	11	-	3	32	35
South Hadley,	8	-	-	-	-	1	-	2	-	1	-	-	4	1	1	8	1	7	4	6	1	-	4	-	26
Spencer,	6	-	-	-	-	-	-	1	1	-	6	-	-	-	-	9	1	20	11	6	4	-	3	2	38
Springfield,	97	-	17	9	20	13	20	4	3	7	18	-	25	1	30	147	14	117	47	43	64	14	68	27	492
Stoneham,	11	-	-	-	3	-	1	1	1	-	-	-	-	-	1	10	-	16	18	16	15	-	5	-	25
Stoughton,	14	-	-	-	1	-	1	1	-	-	2	-	4	-	-	12	3	5	-	1	5	-	3	-	54
Swampscott,	14	-	1	-	-	-	-	1	-	-	-	-	-	-	-	16	1	20	7	11	3	1	4	-	17
Taunton,	52	-	-	2	4	2	6	2	3	-	12	-	14	4	55	99	25	54	6	33	19	7	16	-	308

Wakefield,	13	-	-	1	1	1	2	6	-	-	-	-	-	4	1	13	1	18	20	6	10	-	4	-	43
Waltham,	38	-	-	1	6	-	6	-	1	-	10	-	4	3	8	43	10	55	52	15	13	5	13	28	75
Ware,	17	-	1	1	3	2	-	-	-	-	-	-	6	-	1	32	2	9	16	7	5	-	2	-	65
Watertown,	19	-	-	2	2	-	-	10	-	1	-	-	1	-	4	21	3	27	14	5	6	1	11	15	38
Webster,	18	-	-	-	3	-	-	2	-	-	1	-	5	2	5	20	3	19	4	10	6	1	5	-	53
Wellesley,	5	-	-	-	-	-	-	2	-	-	-	-	-	1	3	4	1	12	4	4	4	-	2	3	16
Westborough,	22	-	1	-	1	-	1	-	1	-	3	-	-	-	-	19	4	31	65	15	5	1	8	-	20
Westfield,	18	-	-	1	3	-	3	-	2	-	2	-	1	2	-	26	7	19	15	15	16	-	6	-	94
West Springfield,	13	-	1	1	4	-	-	6	-	-	2	-	8	-	2	9	2	12	3	8	3	1	2	-	48
Weymouth,	25	-	-	1	1	1	1	3	-	-	1	-	3	4	5	27	6	40	27	8	15	-	5	6	58
Whitman,	7	-	1	-	-	-	-	8	-	-	1	-	2	-	-	7	2	16	10	3	4	2	2	-	16
Williamstown,	6	-	-	-	-	-	-	-	1	-	1	-	2	-	1	11	2	10	9	3	2	-	4	-	9
Winchendon,	3	-	-	-	-	-	-	3	-	-	-	-	1	1	1	6	3	7	12	4	3	-	1	-	30
Winchester,	6	-	1	-	-	-	-	1	-	1	1	-	-	1	5	14	2	10	3	3	9	-	1	3	37
Winthrop,	7	-	-	-	1	-	1	-	-	-	1	-	3	-	1	9	-	11	25	19	16	-	3	-	12
Woburn,	23	-	-	2	2	3	-	3	1	-	4	2	9	-	18	19	5	29	31	23	8	1	3	5	71
Worcester,	186	-	12	25	84	21	18	52	9	7	25	2	194	-	33	266	52	216	285	108	131	20	100	1	725
	4,142	4	146	267	697	217	333	530	131	104	416	22	1,525	142	1,263	4,806	1,152	4,925	3,767	2,445	2,237	361	1,921	574	14,477

	Homicide.
Abington,	1
Boston,	33
Brockton,	1
Easthampton,	1
Gardner,	1
Holyoke,	1
Hyde Park,	1
Lawrence,	2
Leominster,	1
Lynn,	1
Malden,	1
Medford,	1
New Bedford,	1
Somerville,	1
Springfield,	5
Taunton,	2
Watertown,	1
Woburn,	2
	57

	Actinomycosis.
Boston,	2
	Hydrophobia.
Boston,	1
Framingham,	1
Westfield,	1
	3
	Malignant Pustule.
Boston,	1
	Glanders.
Boston,	1
	Anthrax.
Lynn,	2
	Tetanus.
Plymouth,	1

Table IV.

Deaths from Specified Causes, 1907, in Cities and Towns required to report to the State Board of Health, Death-rates per 10,000 (1903–07), Deaths per 1,000 from All Causes, 1903–07.

Causes of Death.	Deaths 1907.	Mortality per 10,000 of the Population.					Deaths per 1,000 from All Causes.				
		1907.	1906.	1905.	1904.	1903.	1907.	1906.	1905.	1904.	1903.
Consumption,	4,142	15.50	15.11	16.01	16.05	15.66	88.75	91.00	95.46	103.76	97.06
Smallpox,	4	0.01	–	0.008	0.03	0.08	0.09	–	0.046	0.20	0.31
Measles,	146	0.55	0.58	0.61	0.63	0.69	3.13	3.49	3.62	4.04	4.27
Scarlet fever,	267	1.00	0.43	0.43	0.48	1.75	5.72	2.60	2.56	2.77	10.85
Diphtheria and croup,	697	2.61	2.50	2.20	2.38	2.94	14.90	15.03	13.13	15.39	18.50
Whooping cough,	217	0.81	1.72	0.64	0.45	1.64	4.65	10.35	3.78	2.92	10.19
Typhoid fever,	333	1.25	1.64	1.87	1.59	1.81	7.14	9.87	11.15	10.29	11.24
Cerebro-spinal meningitis.	530	1.98	1.78	2.36	1.13	1.33	11.36	10.71	14.10	7.28	8.23
Erysipelas,	131	0.49	0.43	0.52	0.58	0.35	2.81	2.58	3.11	3.77	2.16
Puerperal fever,	104	0.39	0.28	0.34	0.27	0.33	2.23	1.71	2.00	1.72	2.04
Influenza,	416	1.56	0.51	1.22	0.77	1.06	8.91	3.08	7.26	4.97	6.60
Malarial fever,	22	0.08	0.06	0.13	0.11	0.16	0.47	0.36	0.78	0.74	1.02
Cholera infantum,	1,525	5.71	5.59	5.88	5.21	5.89	32.67	33.70	35.05	33.67	36.50
Dysentery,	142	0.53	0.58	0.62	0.63	0.62	3.04	3.49	3.71	4.07	[illegible]
Diarrhœa and cholera morbus.	1,263	4.73	4.10	4.15	3.59	3.29	27.06	24.72	24.74	23.21	20.36
Pneumonia,	4,806	17.98	17.72	17.75	15.85	16.48	102.98	106.72	105.85	102.46	102.11
Bronchitis,	1,152	4.31	4.19	4.31	4.23	4.55	24.68	25.27	25.69	27.37	28.17
Diseases of the heart,	4,925	18.43	17.00	17.36	16.21	15.25	105.52	102.40	103.50	104.79	94.52
Diseases of the brain and spinal cord.	3,767	14.10	12.46	14.74	12.56	11.15	80.72	75.08	87.88	81.24	69.10
Diseases of the kidneys,	2,445	9.15	8.95	9.01	8.24	8.45	52.38	53.90	53.75	53.30	52.36
Cancer,	2,237	8.37	8.13	7.97	7.34	7.05	47.93	48.96	47.55	47.49	43.70
Suicide,	361	1.35	1.00	1.09	1.03	1.05	7.74	6.01	6.52	6.69	6.50
Accident,	1,921	7.19	6.29	5.88	5.14	5.43	41.16	37.87	35.06	33.25	33.66
Unknown or ill-defined causes.	574	2.15	1.98	2.00	1.70	1.91	12.30	11.95	11.96	10.98	11.84
All causes,	46,671	174.65	166.10	167.67	154.65	161.32	–	–	–	–	–

REPORTS OF LOCAL BOARDS OF HEALTH.

The following digest consists chiefly of extracts from the annual reports of the boards of health of cities and towns for the year 1907, illustrating the character and extent of the sanitary work performed by the local authorities.

One hundred and seventy-four cases of smallpox were reported for the year 1907, 112 of these having occurred in Lawrence. Forty-two were reported for the year 1906, 44 for the year 1905, 100 for the year 1904 and 417 for the year 1903.

There was an increase in the number of reported cases of scarlet fever for the year 1907, as compared with the number reported for 1906. In Lawrence there were 105 cases and 5 deaths, the fatality being 4.7 per cent., as against a fatality of 3.2 in 1906. In Boston there were 2,410 reported cases and 49 deaths, a fatality of 2 per cent.; in Cambridge, 384 cases with 10 deaths, the fatality being 2.6 per cent.; in Fall River, 95 cases with 7 deaths, the fatality being 7.4 per cent.; in Somerville the fatality was 3.0 per cent.; in Worcester, 9.7 per cent.; in Lowell, 3.5 per cent.; in Springfield, 3.0 per cent.; in Newton, 2.7 per cent.

The following numerical statement of bacteriological work performed by local boards of health is also taken from the annual reports of those boards for the year 1907: —

Bacteriological Work performed by Local Boards of Health and by the State Board of Health, 1907.

	Diphtheria Cultures.	Tuberculosis.	Typhoid Fever.	Malaria.
Agawam,	10	-	-	-
Amherst,	11	-	-	-
Belchertown,	1	-	-	-
Boston,[1]	13,286	4,768	1,512	180
Brockton,[2]	372	431	130	69
Brookline,	775	169	76	32
Cambridge,[3]	1,770	466	205	-
Chester,	6	-	-	-

[1] Glanders, 208; other diseases, 515. [2] Other diseases, 50. [3] Other diseases, 9.

Bacteriological Work performed by Local Boards of Health, etc. — Concluded.

	Diphtheria Cultures.	Tuberculosis.	Typhoid Fever.	Malaria.
Chicopee,	96	29	-	-
East Longmeadow,	42	-	-	-
Granville,	27	-	-	-
Greenfield,	24	-	-	-
Haverhill,	264	-	-	-
Hardwick,	8	-	-	-
Holyoke,	586	49	8	-
Huntington,	1	-	-	-
Longmeadow,	14	-	-	-
Lowell,[1]	2,133	478	200	3
Middlefield,	1	-	-	-
Montague,	6	-	-	-
New Bedford,	430	144	-	-
Newton,	875	47	49	-
Northampton,[1]	196	64	-	-
Palmer,	73	-	-	-
Somerville,	971	227	110	-
South Hadley,	7	-	-	-
Springfield,	1,605	172	75	-
Ware,	110	-	-	-
Westfield,	2	-	-	-
West Springfield,	12	-	-	-
Wilbraham,	5	-	-	-
Worcester,	8,617	486	-	-
State Board of Health,[2]	4,646	1,705	705	31

[1] Other diseases, 8.
[2] The State Board of Health figures for 1906 should have been for the fourteen months ended Nov. 30, 1906, and should have read: diphtheria cultures examined, 4,133; tuberculosis, 1,576; typhoid fever, 820; malaria, 21.

Attleborough.

The attention of physicians and householders was called to the revised list of diseases declared on August 1 by the State Board of Health to be dangerous to the public health.

The board of health acted upon the statute provisions relative to medical and surgical appliances in factories and workshops, and warned the proprietors of said establishments that there was a severe fine for not keeping the articles upon their premises.

Boston.

The total number of deaths for the year was 11,686, an increase over the previous year of 275 deaths. The estimated population, in the middle of the year, is 609,757. The death-rate for the year, as calculated on this population, is 19.16 per 1,000 inhabitants. This rate was greater by 0.26 than that of the previous year, but lower by 0.34 than the average of the previous ten years. There were 2,096 deaths from infectious diseases, a decrease of 23 deaths. There were 8 less deaths from diphtheria and croup than in 1906, and an increase in the number of cases. The percentage of deaths to the number of cases of diphtheria reported was 6.09, as against 7.00 per cent. the preceding year. There were 49 deaths from scarlatina, 10 more deaths than in the preceding year, and 42 deaths less than the average for the ten previous years. Typhoid fever caused 64 deaths during the year, 58 less deaths than the preceding year. Eighteen of the deaths from this cause occurred during the months of August, September and October, and 37 of the whole number died between the ages of twenty and forty years.

There were 29 deaths from measles during the year. The number of deaths of children under five years of age was 3,160, compared with 3,439 for the previous year, showing a decrease of 279 deaths. The respiratory diseases caused 22 per cent. of the mortality for the past year.

Consumption. — The death-rate from consumption in Boston has steadily decreased for many years, and particularly so during the last twenty years. The highest recorded death-rate from this disease in Boston occurred in 1853, when it amounted to 48.16 in each 10,000 of the population, and the average rate from 1850 to 1855 was 47.36. The death-rate for 1906 was 19.67; for 1907 the rate was 18.42.

Typhoid Fever. — The highest death-rate from typhoid fever in Boston in each 10,000 of the population occurred in 1872, when it amounted to 8.62. The rate for 1906 was 2.02 and for 1907 the rate was 1.05.

Bacteriological Laboratory. — The total number of bacteriological examinations made between Feb. 1, 1907, and Feb. 1, 1908, was 25,148. Of these, 20,467 were diagnoses and 4,681 were milk examinations.

With this report the laboratory completes its tenth year as a sub-department of the board of health. In that time it has made over 150,000 examinations, of which 100,000 were for diphtheria. The total number of routine examinations for 1907 has increased practically five times in that interval.

In addition to the regular routine work, the laboratory has made many analyses of food and water, and various sanitary tests, together with a

considerable number of special investigations along sanitary lines made either at the direct request of the board or resulting from the necessity of keeping abreast of the times in this particular branch of science.

The total number of diphtheria examinations increased 1,225 over the number examined during 1906. Notwithstanding the increase, the percentage of positive cultures dropped from 28 to 26 per cent.

Examinations of sputa for *B. tuberculosis* are increasing at the rate of about 500 examinations per year. The total increase in examinations over the previous year is 1,298, making the average number of examinations per day 69, the largest on record.

Special Investigations. — The following investigations, inspections and analyses have been made at the request of the board: —

1. Effect of light and moisture on the longevity of *B. tuberculosis* in sputum.

2. Tests of embalming fluids.

3. Miscellaneous tests: Pathological examination of lung of cow. Bacterial examination of four samples of water, of which three showed pollution. Several analyses of wall paper and fabrics for arsenic, — all negative. Chemical examination of small stuffed chickens sold as Easter toys, — skin preserved by the use of white arsenic in large quantity. Chemical examination of paper diapers for the Boston Floating Hospital, — nothing injurious or irritating found. Bacterial tests on sample of crude disinfectant. Microscopical examination of pork. Bacterial examination of one sample of canned corn.

Milk Inspection. — During the year there has been a further decrease in the number of milkmen, 28 dealers having abandoned the business. In 1906, 28 wagon dealers also discontinued the sale of milk; thus at the present time the Bureau has 56 less licenses than in 1905. The licensed dealers now number 288. There was a slight decrease in the number of shops engaged in the sale of milk, 3,730 now being registered to deal in this commodity. In 1906 there were 3,746 registered establishments.

Boston now has three sources of certified milk, and the available daily supply amounts to 855 quarts. A new dairy has recently placed its product upon this market. All of these dairies are under the supervision of milk commissions, and the health of the cattle and of employees is of the best, and the utmost cleanliness of cattle, employees, utensils and surroundings prevails. Temperature regulations are insisted upon, and clean, wholesome milk, with not more than 10,000 bacteria to the cubic centimeter, results. The milk is also delivered with comparative freshness.

The replacing of the old style $8\frac{1}{2}$-quart milk can with cans of larger size, for transporting milk by rail to this city, still continues. One concern is now bringing all of its milk into the city in $21\frac{1}{4}$-quart cans, while another company is using this unit for nearly all of its milk supply. Another firm substituted 40-quart cans for about one-half of the $8\frac{1}{2}$-quart cans formerly used. One firm replaced the $8\frac{1}{2}$-quart cans upon one of its cars with $21\frac{1}{4}$-quart cans. All of the contractors who use these larger units feel that such change is conducive to a better milk supply.

The gradual displacement of the $8\frac{1}{2}$-quart can for transporting milk from the country has lessened the misuse of cans by the producer materially. The cans of a larger size are a prohibition against improper use, by reason of their great weight and unwieldiness when filled.

Nearly all of the cans are now washed by contractors before they are returned to the farmer. One concern sends one-fourth of its daily 8,000-can supply to the country unwashed, but the other firms are returning all cans washed. Four of these companies state emphatically that in their opinion the washing of cans has improved their milk supply, and one firm states that present bacteriological results could not have been obtained without washing and sterilizing cans before returning to producers. One firm is of the opinion that the supply has been bettered, but that advantage is taken of the system by producers who disclaim responsibility of rewashing cans which by unavoidable means become soiled in transit.

A marked improvement has been noted in the treatment of milk cans by store and restaurant keepers, and instances are now rare — by comparison with other years — where cans are used as containers of substances like kerosene oil, molasses, broken eggs, etc. Some shopkeepers are even washing the cans before returning them to milkmen. To a great extent the misuse of cans is confined to foreigners, who are ignorant of the law and regulations governing this subject. A majority of the complaints brought to the attention of the Bureau were those where cans had been employed for cooking purposes, in the heating or preparation of soups, chocolate and other substances. In every instance a warning notice served to cause abandonment of this illegal practice.

The distribution of cards to shopkeepers selling milk, relative to the subject of improper use of milk vessels, has assisted materially in directing attention to the necessity for confining the employment of milk containers within proper limitations.

In connection with undesirable dairies the board has published in

its annual report seven photographs showing the bad conditions found at a leased farm in the vicinity of Boston.

Bacteriological Examination of Milk. — During the year 4,681 examinations have been made of samples of milk for bacterial content, the presence of pus and pus-producing organisms. From the mere standpoint of figures, the results from the bacteriological examination of milk samples from contractors is not as satisfactory as in former years. Despite this adverse showing, however, it cannot be gainsaid that progress has been made during the last year towards a cleaner milk supply, and that greater efforts were put forth to suppress filthy supplies than in any previous year since the movement for clean milk began. An important influence upon the number of samples from this source failing to comply with the standard of 500,000 bacteria per cubic centimeter, is the fact that more samples than usual were collected during the warm months of the year, when the bacterial content is highest. In this respect the work is not as indicative of the quality of the milk from contractors as were the samples collected during 1905 and 1906. Another factor affecting percentage results is that fewer samples were collected from contractors who are endeavoring to better their product, and whose work in this direction is meeting with success.

During the year various contracting firms made 29,208 bacteriological examinations of milk, in the endeavor to ascertain the quality of their supplies.

All of the contracting firms agree that the bacteriological work of the last three years in connection with the milk supply has resulted in a marked improvement. One firm states that the amount of sour milk has been reduced 70 per cent. Another firm says that the work of bettering the condition of milk has brought a reduction of 17 per cent. in dairies with milk containing over 500,000 bacteria per cubic centimeter; a reduction of 12 per cent. in dairies with milk having temperatures above 50° F; and a reduction of 12 per cent. in dairies with milk indicating pus. These figures are significant, and demonstrate possibilities where the work of improvement is judiciously planned and persistently and intelligently executed. Two firms have begun to use score cards. Where the milk is persistently faulty, producers are notified to stop sending the milk. This course is also followed by other dealers where designated improvements are not made. Meetings for discussions with producers have been held, and literature upon the clean and cold milk subject has been freely employed. One concern reports but few instances where producers were not supplied with ice.

Warnings were sent by the board for the first violation of the temperature regulation, and in all 216 were issued during the year; 92 of

these were forwarded to contractors, and represented milk of high temperature just as it arrived from the country. Where warnings proved unavailing, prosecutions were instituted, and in all 20 cases were brought.

Cream. — After the enactment of the law last year, which made it illegal to sell cream having less than 15 per cent. of milk fat, it was found that very few of the dealers were aware of the adoption of this standard. To acquaint them with the requirements of the measure, several thousand copies of the law in circular form were distributed. These notices also called attention to the regulations of the board of health concerning the standards for bacteria and temperature. The issuing of this circular resulted in an immediate improvement of the low-grade creams, and very few samples are now found which do not have the required per cent. of fat. A marked change for the better was also made in the mode of handling cream after its arrival in this city.

Butter. — Although there was not much variance in the number of cases for violation of the renovated butter law, there can be little doubt that the number of dealers in this commodity is gradually decreasing.

Oleomargarine. — The sale of this substance is rapidly increasing. This is largely due to the attitude of the courts in interpreting the color law of this State. Oleomargarine of the yellow type is viewed with favor by restaurant and boarding-house keepers. This is demonstrated by the increased number of cases against these establishments where oleomargarine was being served without notifying guests. During the year 26 cases were entered for serving oleomargarine in the above manner, as against 6 cases in 1906.

Brockton.

Milk Inspection. — From the office of the board of health there have been sent out notices to every person from whom milk has been taken which has been found to contain bacteria in numbers above 500,000, or which contained pus or streptococci, a record of such being kept in card form.

Bacteriological Examination of Milk Samples. — Comparison of the figures of 1907 with those of 1906 shows a marked improvement in the bacterial content of milk put upon the market during the year.

The system of scoring dairies, originated by the United States Department of Agriculture, has been adopted by the board. Various dairies have been visited, inspected and scored by this method. It is a matter of some satisfaction to the board that, in view of the criticism launched at the time of beginning the inspection, — that to produce milk that would conform to the required regulations would require enormous expense

on the part of the farmer in the way of costly apparatus and general remodelling of the farm, — it is able to present with its annual report photographs of the two dairies that are tied with each other for the record of producing the cleanest milk sold in Brockton, as shown by the inspection of 1907. From the teams of each of these dairies throughout the season seven samples were collected, the results in each case averaging below 10,000 bacteria per cubic centimeter.

Records showing the standing of the individual dealers are kept at the board of health office, and are available for consultation by householders and physicians desirous of ascertaining whether they or their patients are being supplied with clean milk. The constant inquiries received at the office for such information is evidence of the considerable interest taken by the public in this work.

Brookline.

General Health. — The past year has been somewhat memorable in local health matters in a number of ways.

Tuberculosis. — The general awakening to the need of more protection against tuberculosis, and the recognition of the practical value and success of recent methods of preventing and curing the disease, resulted the past year in the formation of the Brookline Anti-Tuberculosis Society, which now has a membership of about 200. The society is directing its efforts toward the proper care of needy tuberculosis patients in sanatoria and hospitals where possible, and in other cases in their homes; toward educating the citizens as to the causes and prevention of the disease; toward aiding persons recently cured of tuberculosis or relieved from its active symptoms in securing suitable employment; and finally, toward aiding the Brookline health department in every possible way in their efforts to prevent the spread of the disease. The society gave an eight-day "Tuberculosis Exhibit," in the course of which a number of public meetings were held, addresses were given, stereopticon illustrations were shown and much real interest was aroused. The total attendance was nearly 3,000.

The building for tuberculous patients who cannot be admitted to the State Sanatorium at Rutland has proved very useful, and at present 5 young men, all from tenement homes, are cared for in it. Facilities for out-door treatment, "head-tents" for out-door sleeping for suitable cases, and other measures to secure comfort, prevent reinfection and promote recovery where possible, are employed. More of the town's people are awakening to the need of fundamental, systematic and persistent efforts to stamp out tuberculosis.

Contagious Hospital. — During the summer the wooden building originally used for diphtheria patients was considerably altered and a good heating plant was put in, thus making the hospital serviceable for the comfortable accommodation of from 10 to 15 patients in time of need. There were also repairs and repainting of portions of the newer buildings during the summer.

Milk Inspection. — One result of the increased restriction and supervision of the local milk supply has been to compel the retirement of several small dealers who could not afford the proper appliances for meeting the required conditions. Two retired under compulsion, while others withdrew voluntarily. The co-operation of reputable dealers in securing and sending in suspicious samples, and the increased supervision incident to the increased cost of food stuffs, has added to the work of the department, but the result in maintaining the standard of the milk supply without the necessity for prosecution has been satisfactory. A minor improvement has been the suppressing of unnecessary noise in the exchange of milk cans among drivers in the early morning.

Constant vigilance has been necessary to secure proper sanitary conditions in stores where milk and other food products are sold. Most of these are kept under proper conditions, but there are enough owners who are careless or indifferent to require frequent visits of the inspector. Nine stores were prohibited from keeping milk in the dilapidated ice chests in use, and in which other food stuffs were stored. In ten other stores new ice chests were installed, and in four others filthy surroundings of the ice chests were corrected. Extreme care in the cleansing of returned jars and bottles has prevented the transmission of disease thereby, so far as has appeared.

The Dust Nuisance. — The past two or three years, owing to the increasing number of electric cars and automobiles, the streets have become more and more a source of great annoyance, and at times a real menace to the health, by reason of the clouds of dust raised by the peculiar construction and rapid motion of these vehicles. Over a year ago the Brookline Medical Society passed resolutions on the subject, and appointed a committee to confer with the board of health as to measures for relief from this dust nuisance. In view of these facts, the superintendent of the street department was authorized to do more sprinkling, and also to conduct experiments in methods of dust prevention. These were made with a 7 per cent. solution of calcium chloride in parts of the town, and in other parts with an oil compound.

The superintendent of streets, the town engineer and the agent of the board of health were requested to observe the results of these trials, and

to report on the safety, effectiveness and general merit of these methods. Special attention was given to the calcium chloride treatment, and two special reports were made on it.

The municipal gymnasium is now well established, and there is evidence that it will mean in the life of the town what its friends have expected of it. The regrettable conditions in Village Square, where the sanitary conditions were in certain respects most deplorable, are now rapidly disappearing. All public school pupils are now to have adequate supervision by specialists, in order to save them from preventable deafness, eye-strain, decay of teeth, nervousness, obstructed respiration,— factors that favor mental and moral impairment.

Cambridge.

After several weeks of experimental work in the schools of East Cambridge, the board of health, feeling it to be a public necessity, engaged a school nurse. This nurse works directly under the board of health, in conjunction with the school inspector and in co-operation with principals and teachers.

In September, 1907, a circular letter was sent to the physicians of Cambridge, relative to diseases declared by the State Board of Health to be dangerous to the public health.

Contagious Hospital. — The Legislature has, upon petition of the city, passed an enabling act whereby the city of Cambridge may raise $150,000 outside of its debt limit for the establishment of a contagious hospital. A location has been determined upon, and an order has been passed providing for an appropriation of $20,000, which will enable the board to begin work upon the hospital.

During the season just passed there has been a marked improvement in the conditions pertaining to the sale of groceries and provisions, and in general the provision and fruit stores are in excellent condition. Where there has been any cause for complaint, a suggestion from the inspector has immediately resulted in the removal of such cause.

The ice cream manufactories have been closely inspected, and the inspection has been made thorough by frequent visits of the inspector, and, as a result, the conditions have been very much improved.

Gloucester.

During the late spring, as a result of investigation on the part of the board, it was learned that the manufacture of ice cream in certain establishments was being conducted in a manner that was not wholly in keeping with regulations governing such products. After visiting all the local places, action was taken against four dealers, who were ordered

to close up until certain improvements had been made, satisfactory to this board.

The board later decided to take measures against hokey-pokey carts. Numerous complaints have been made in previous years regarding the sale of cream from hokey-pokey carts to the children, and in the interest of public health the board decided that such carts should hereafter be discontinued.

School Inspection. — In connection with medical inspection of children in the schools, the board calls attention to the needs of a dentist. This movement would be in accord with the examination of school children for contagious diseases, and would have a similarly beneficial effect. The board also recommends such legislation as would provide glasses for needy children, free, or at a small nominal cost; and calls attention to the Revised Laws relative to diseases declared by the State Board of Health to be dangerous to the public health.

Haverhill.

In June a tuberculosis exhibit was given by the board of health in the city hall, which continued for one week. Modern methods of prevention and the out-door treatment of those afflicted were shown, and by daily lectures the public was made aware of the deadliness of the tuberculosis plague, and instructed in methods of prevention, alleviation and cure. Great interest was shown by the large number in daily attendance. The board has prepared for distribution a circular folder instructing patients and persons as to the manner of handling cases of tuberculosis.

School Inspection. — The results of medical inspection in the public schools have been so satisfactory that it seems advisable to recommend an increased appropriation to extend the work to the four parochial schools, whose authorities would be willing and glad to have their schools included in such inspection.

The board recommends the appointment of at least two nurses to assist the school inspectors in carrying on this work.

Much attention has been paid during the past year to bakeries, hotels and restaurants, the result of which is apparent in the improved conditions in these places.

Holyoke.

Under authority of chapter 502 of the Acts of 1906, entitled "An Act relative to the appointment of school physicians," an appropriation was made and medical inspection of schools was begun. Six physicians were appointed to carry on the work.

Lawrence.

The total number of contagious diseases reported to the board of health during the year 1907 was 654. The number reported in 1906 was 755, and in 1905, 882. During all this period the population of the city has been steadily and rapidly increasing; therefore, while the actual decrease has been 228 since 1905, the relative decrease has been much greater.

School Inspection. — The act providing for the appointment of school physicians went into effect Sept. 1, 1906, and immediately thereafter a school physician was appointed and assigned to duty. Later, an appropriation was granted by the city council, and five physicians were appointed and entered upon their duties Sept. 1, 1907. Their work has been very satisfactory, and only needs to be known to be thoroughly appreciated by the public.

Tuberculosis Exhibit. — A special appropriation of $100 was obtained, and the free use of the city hall for one week was granted, for the purpose of holding a tuberculosis exhibition. The exhibition was held in October, under the direction of the Massachusetts Society for the Control and Prevention of Tuberculosis, and was a marked success. As a sequel to the exhibition, an Anti-Tuberculosis Society has been formed in the city, which will continue the work of education in the necessary means for the prevention of the spread of this scourge. The board of health is also doing all in its power to abolish the many practices which tend to propagate tuberculosis, — notably, the filthy habit of expectorating on the sidewalks and in public places. For this purpose the board has ordered 2,000 warning signs, and will have them properly posted.

The board has made the following recommendations: —

The establishment and maintenance by the city of a public general hospital.

That immediate steps be taken toward the installation of some approved incinerator for the destruction of waste collected.

Lowell.

In January the board passed the following "Regulation for the Public Health and Safety:" —

On and after March 1, 1907, the practice of exposing meat, poultry and fish outside of market places will not be allowed.

And in July the following regulation was adopted by the board: —

On and after Aug. 20, 1907, no vehicles containing offal, skins or hides, or meats from wholesale houses, will be permitted to pass through the public streets unless the following regulations be strictly observed: —

All vehicles used by rendering companies to convey offal through the streets shall be completely covered.

Skins and hides shall be completely covered. Dripping pans shall be placed underneath the vehicle, to prevent drippings from such skins or hides from falling on the streets.

All meats from wholesale houses shall be completely covered while passing through the public streets.

The rule relative to the exposing of meats, poultry, fish and game has been observed in a most satisfactory manner, and there has been a vast improvement over last year both in the quality of meats, etc., and in the manner in which they are handled.

MEDFORD.

The widespread interest in the anti-tuberculosis movement has led the board to procure and have on hand, for the use of physicians, nurses and others interested, copies bound in paper of Dr. S. A. Knopf's international prize essay on "Tuberculosis as a disease of the masses, and how to combat it."

The attention of the public is called to the Acts of 1907, chapter 410, prohibiting expectoration in public places, etc.; chapter 480, the compulsory notification and registration of tuberculosis and other diseases dangerous to the public health; chapter 503, in regard to providing proper receptacles for expectoration.

On Aug. 30, 1907, the act to provide for keeping medical and surgical appliances in factories became operative, and the board caused a list of the necessary appliances to be posted in thirty-five establishments.

NEW BEDFORD.

During the year the board has given particular attention to the production of milk. Nearly every farm where milk is produced for distribution in New Bedford was made the subject of a special investigation, and in most instances the owners of cows readily complied with the orders given, those who refused being prohibited from making a further distribution in this city. Examinations of milk for bacteria have been made for the past two months, and a systematic examination is being inaugurated, which the board is of opinion will greatly assist in the effort to secure a wholesome supply for the residents of this city.

NEWTON.

The supervision of dairies has taken up a good deal of the work of the board during the year, and it is believed that a marked improvement in the condition of these dairies has been brought about. The

policy of the board has been to give the producer every opportunity to keep his buildings clean and neat, and to require the most glaring faults to be remedied at first, and later the minor objections, in this way trying to bring the conditions nearer and nearer to the ideal. In only one instance was it found that the producer was unwilling to conform to the requirements of the board, and an order was passed depriving him of his license to keep cows. The inspector of milk has co-operated with the board in this work, and has been of great assistance. He has been of special assistance in dealing with dairies outside the boundaries of the city.

North Adams.

For the purpose of insuring the cleanliness of food, the board has enacted rules relative to "the exposure for the purpose of sale, of articles of food."

Bacteriological Work. — Heretofore it has been necessary to send diphtheria cultures to the State Board of Health for examination. In order to save time in establishing diagnosis, and in order to save both time and money in releasing from quarantine in cases of diphtheria, the board has secured the co-operation of a physician in the city, who has fitted up a laboratory, almost entirely at his own expense, where bacteriological examinations of suspected cultures are made with expedition and precision, the board paying for each examination. The saving in quarantine expense has certainly exceeded this small amount. The laboratory is also equipped for examining specimens of sputum and for making the Widal test for typhoid fever. The board is making use of the diphtheria and tuberculosis examinations in the work of medical inspection of schools.

Milk Supply. — In order to control the milk supply at its source, inspection was made of all of the dairies from which the city obtains its milk.

School Inspection. — In April, 1907, an appropriation was granted for the work of medical inspection in the schools, and immediately five physicians were appointed by the board to carry on the work.

Somerville.

Ashes and Offal. — The collection and disposal of ashes, garbage and other refuse materials is under the control of the board of health, and a competent superintendent is employed to take charge of this department. The incinerator was put into operation early in September, and has worked very satisfactorily. In order that the combustible and noncombustible materials might be kept separate as far as possible, a circular

was prepared by the board and distributed throughout the city to householders and others having waste materials for removal.

In May the board passed regulations for the sale and care of milk, and for the keeping of medical and surgical appliances in factories. The regulation requiring that milk be kept at a temperature not to exceed 50° F. has been productive of good, and is very generally complied with. In July a microscope was purchased for the use of the milk inspector, and 164 examinations of samples of milk for bacteria, pus, and dirt have been made. A new set of analytical balances has also been purchased this year. There has been a great improvement during the past year in the quality of the milk sold in Somerville and in the method of handling it.

Springfield.

School Inspection. — The results of the first full year's medical inspection of schools in this city have been most gratifying to the board of health. During the first half of 1906, inspection was confined to the public school children, but in September, 1907, the work was extended to the parochial schools.

The total number of children examined during the past year was 8,759, and there were 1,043 excluded from school by reason of communicable disease, or illness which made their attendance at school inadvisable.

Stoughton.

The board has published in its report for 1907 the following acts: —

To provide for the keeping of medical and surgical appliances in factories; and a list of the articles to be kept at hand for emergency use.

Relative to sanitary conditions in factories and workshops.

Further to prohibit expectoration in certain public places and conveyances.

To provide for the compulsory notification and registration of tuberculosis and other diseases dangerous to the public health.

Waltham.

A rigid inspection of all dairies has been carried out, defects noted, and recommendations for the betterment of conditions made to the owners. Failure to comply has resulted in the revocation of the license.

During the year the board has instigated a searching investigation into the condition of markets, with a view to eliminating all objectionable features. It is required that no meats be conveyed through the streets unless they are properly covered and protected against dust particles.

In accordance with the law recently passed, the board has brought about the installation in all manufactories of emergency cases, containing such articles as are necessary in the treatment of sudden illness or accident of an employee.

Whitman.

The board is carrying on the work of milk inspection in the same manner as last year. In the spring all stables where cows are housed, the cows, and all utensils and water supplies, were inspected. Tests were made for bacteria, and the board finds that it is getting the best results along this line, as the percentage of bacteria is very much less than when the work was begun.

The board again calls the attention of the citizens to the great necessity of a system of sewerage for the town. On account of the location of Brigham Pond, and the fact that several house drains discharge their contents into it, it was thought best to prohibit the cutting of ice on the pond for domestic purposes, and an order to that effect was issued.

In accordance with the act to provide for the keeping of medical and surgical appliances in factories, a circular was prepared and sent to each of the manufacturers to whom the law applied. The circular contained a copy of the act and a list of medical and surgical appliances.

Winchendon.

The board of education, in accordance with the law, has appointed a school physician, who has charge of the work of medical inspection.

The board of health has published in its annual report a list of diseases declared to be dangerous to the public health, and the law relative to ophthalmia neonatorum.

Woburn.

Bakeries. — With one exception, the bakeries in Woburn are located in buildings that are old, dimly lighted and poorly ventilated. At the first inspection some of these places were found by the board to be in a very unsanitary and unsatisfactory condition. The statutes require that the laws relating to bakeries shall be posted in the bakeries and in the places of business. None was found in any of these, and the board had prepared and posted in each store and work room a copy of the law as required. Changes in some of the work rooms, involving no inconsiderable expense to the owners of the buildings, were promptly made. Other changes and improvements are yet needed in some of them to make them conform to the spirit of the statutes and the laws of cleanliness and health.

WORCESTER.

The bacteriological laboratory has been very busy during the year just closed. There were 8,617 diphtheria cultures examined during the year, and 486 specimens of sputum. Typhoid fever and malaria have been added to the diseases for which the laboratory is offered as an aid in diagnosis. By the addition of these the bacteriological laboratory has been placed on a par with the best laboratories of the country.

Diphtheria. — The unusual prevalence of diphtheria, which began in August, 1906, continued throughout the year 1907, an average of nearly 100 a month being maintained throughout the year. In all, 1,178 cases were reported, with 84 deaths, — a mortality of 7.11.

In July the city council issued the following order: —

Ordered, That the board of health be and is hereby authorized and directed to report to the city council on the general health of the city, with special reference to the prevalence and spread of diphtheria, its cause and methods of prevention; also report on the status of consumption, and what steps are needed to check and suppress the spread of the disease; and the board may make such further suggestions and statements as may help to prevent an epidemic of scarlet fever or other infectious disease with which this city is or may be threatened.

In accordance with the above order, the board made its investigation and submitted a report, in which were made many valuable recommendations relative to an increased force of sanitary inspectors, medical inspectors, an additional ward for scarlet fever at the hospital, the care of ashes and garbage, etc.

The hospital has cared for nearly twice as many patients as in any previous year of its history, and 80 per cent. of these were cases of diphtheria. The additions to the hospital, now nearing completion, provide a new boiler plant and enlarge the administration building, but increase the capacity for diphtheria patients only. There still remains the urgent need of more scarlet fever rooms, and a building for measles and mixed infections.

INDEX.

INDEX.